AN INTEGRATED RISK MANAGEMENT MODEL FOR RECOVERY PROJECTS IN THE CONSTRUCTION SECTOR

A PROPOSAL AFTER THE CANTERBURY EARTHQUAKES, NEW ZEALAND

Ashraf ElSaid ELHassanein Ahmed Abouelezz

Department of Civil and Natural Resources Engineering

University of Canterbury

OCT 2019

Committee:

< Professor: Tom Cochrane >, Ph.D.

< Dr Vicente Gonzalez >, PhD.

< Dr Jorge Rueda-Benavides >, PhD.

< Dr Eric Scheepbouwer >, PhD. supervisor

Doctor of Philosophy in Civil Engineering

Acknowledgements

"All praise is due to Allah Alone, the Lord [the Sustainer, the Cherisher] of the worlds."

Author appreciated the partial financial support from Fulton Hogan and NZTA and to SCIRT for access to data and staff for participating in the data collection. No findings assume any responsibility to the sponsors or participants of the study.

I would like to express my sincere gratitude to my senior supervisor Dr. Eric Scheepbouwer for the continuous support of my Ph.D study and for his patience, motivation, and immense knowledge.

Besides my advisor, I would like to thank the rest of my thesis committee: Dr. Vicente Gonzalez, and Dr. Jorge A. Rueda, for their insightful comments and encouragement, but also for the hard question which encouraged me to widen my research from various perspectives. Also, especial thanks for Dr. Tom Cochrane for organising the defence meeting.

Abstract

The increase of the world's population located near areas prone to natural disasters has given rise to new ‘mega risks’; the rebuild after disasters will test the governments’ capabilities to provide appropriate responses to protect the people and businesses. During the aftermath of the Christchurch earthquakes (2010-2012) that destroyed much of the inner city, the government of New Zealand set up a new partnership between the public and private sector to rebuild the city’s infrastructure. The new alliance, called SCIRT, used traditional risk management methods in the many construction projects. And, in hindsight, this was seen as one of the causes for some of the unanticipated problems.

This study investigated the risk management practices in the post-disaster recovery to produce a specific risk management model that can be used effectively during future post-disaster situations. The aim was to develop a risk management guideline for more integrated risk management and fill the gap that arises when the traditional risk management framework is used in post-disaster situations. The study used the SCIRT alliance as a case study. The findings of the study are based on time and financial data from 100 rebuild projects, and from surveying and interviewing risk management professionals connected to the infrastructure recovery programme.

The study focussed on post-disaster risk management in construction as a whole. It took into consideration the changes that happened to the people, the work and the environment due to the disaster. System thinking, and system dynamics techniques have been used due to the complexity of the recovery and to minimise the effect of unforeseen consequences. Based on an extensive literature review, the following methods were used to produce the model. The analytical hierarchical process and the relative importance index have been used to identify the critical risks inside the recovery project. System theory methods and quantitative graph theory have been used to investigate the dynamics of risks between the different management levels. Qualitative comparative analysis has been used to explore the critical success factors. And finally, causal loop diagrams combined with the grounded theory approach has been used to develop the model itself.

The study identified that inexperienced staff, low management competency, poor communication, scope uncertainty, and non-alignment of the timing of strategic decisions with schedule demands, were the key risk factors in recovery projects. Among the critical risk groups, it was found that at a strategic management level, financial risks attracted the highest level of interest, as

the client needs to secure funding. At both alliance-management and alliance-execution levels, the safety and environmental risks were given top priority due to a combination of high levels of emotional, reputational and media stresses. Risks arising from a lack of resources combined with the high volume of work and the concern that the cost could go out of control, alongside the aforementioned funding issues encouraged the client to create the recovery alliance model with large reputable construction organisations to lock in the recovery cost, at a time when the scope was still uncertain.

This study found that building trust between all parties, clearer communication and a constant interactive flow of information, established a more working environment. Competent and clear allocation of risk management responsibilities, cultural shift, risk prioritisation, and staff training were crucial factors. Finally, the post-disaster risk management (PDRM) model can be described as an integrated risk management model that considers how the changes which happened to the environment, the people and their work, caused them to think differently to ease the complexity of the recovery projects. The model should be used as a guideline for recovery systems, especially after an earthquake, looking in detail at all the attributes and the concepts, which influence the risk management for more effective PDRM. The PDRM model is represented in Causal Loops Diagrams (CLD) in Figure 8.31 and based on 10 principles (Figure 8.32) and 26 concepts (Table 8.1) with its attributes.

Definitions

In this study,

- **Traditional Risk Management (TRM)** refers to the procedure of risk management in construction projects in Business as Usual (BAU) where the project considered being in a static working situation with a stable regulatory environment and low involvement of third-party insurance with no influence of a disaster.
- **Risk Management Framework (RMF)** refers to the stages of governance that are promoted by International Organization for Standardization (ISO) to manage the risks in a system including integration, design, implementation, execution, and improvement (ISO 31000, 2018).
- **Risk Management Process (RMP)** refers to the structured procedures that are promoted by ISO to implement risk management in a system including establishing context, risk assessment, risk treatment, recording and reporting, monitoring and reviewing, and communication and consultation (ISO 31000, 2018).
- **Post-Disaster Risk Management (PDRM)** refers to the risk management practices used to avoid or minimise the impact of risks in recovery projects after a disaster.
- **Post-Disaster Recovery System (PDRecS)** refers to identities or organisations that have been created to manage the recovery programme and to rebuild the city after a disaster such as SCIRT alliance.
- **Post-Disaster Risk Management (PDRM) model** refers to the developed risk management guideline that could be used, developed specifically for recovery projects.
- **Recovery Projects** refer to the construction projects that have been created to recover from a disaster such as a project to rebuild road and infrastructure to recover from an earthquake.
- **The Target Outturn Cost (TOC)** refers to the agreed target cost of the project among all parties.
- **Cost Overrun** is defined as the difference between the final actual cost of a project and the target cost agreed upon by all parties.
- **Project Risk Management (PRM)** refers to the risk management practices used to avoid or minimise the impact of risks in project delivery levels.
- **Enterprise Risk Management (ERM)** refers to the risk management practices used to avoid or minimise the impact of risks in programme levels.

- **Strategic Risk Management (SRM)** refers to the risk management practices used to avoid or minimise the impact of risks in client levels.
- **Intelligent Risk Management Information Systems and Procedures (IRMISP)** refer to the technology used to facilitate the risk management process in recovery systems such as software that controls the risk information between sites and the management team and keep it up-to-date. For example, allowing staff to give input on risksusing mobile devices as risks in recovery projects appear during the operation due to the unforeseen conditions after a disaster.
- **System Thinking (ST)** is defined as an approach that is used to investigate a system as a whole rather than separate parts (Senge, 1990).
- **System Dynamics (SD)** is an approach using mathematical methods and modelling techniques to understand complex systems and nonlinear behaviours, issues and problems (Radzicki & Taylor, 2008)
- **Relative Importance Index (RII)** is a method of ranking used in research to endorse the decision-making (Holt, 2014).
- **Analytical Hierarchical Process (AHP)** is a structured decision-making method, which uses mathematics to deal with complex decisions (Saaty & Peniwati, 2008)**.**
- **Qualitative Comparative Analysis (QCA)** is an analysis method to capture the complex causations between the different variables in a complex system (Rihoux & Ragin, 2008).
- **Grounded Theory Approach (GTA)** is the analysis of data to search out the concepts behind the facts by looking for codes, concepts, and categories (Strauss & Corbin, 1998).
- **Integrated Services Team (IST)** was a team of professional services consultants who provided the design services for the SCIRT programme of work and provided the overarching tactical coordination for the infrastructure rebuild.
- **The framework** is a structured process used to the realisation of defined result or goal**.**
- **A model** is a presentation in a schematic form of the system**.**

Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction to the Study

1.1 Introduction

This chapter underlines the importance of post-disaster research. The background starts by presenting relevant knowledge of the human and financial impacts of disasters globally, and it uncovers the need to focus on Post-Disaster Risk Management (PDRM). Then, a brief look at one of the biggest disasters of New Zealand history, the Christchurch earthquakes, illustrates why that was selected as the study case of present research. Finally, the objectives, the methods, and the structure of this study will be stated.

1.2 Background

The importance of studying risk management after a disaster is undeniable due to its human and economic impacts. The destructive consequences of natural disasters have grown rapidly since the 1980s in both developed and developing countries (Schnarwiller, 2011). Presently, most densely populated areas are also considered to be the most disaster-prone areas where risks can only partially be mitigated (UNISDR, 2004). Based on financial data collected from 40 countries between 1981 and 2011, the total loss due to small and large disasters worldwide was estimated at approximately US$305 billion (UNISDR, 2013). This number covers only the direct losses in housing, local infrastructure and agriculture, and excludes the indirect losses and broader effects of the disasters. The figures also show that the extent of the impact is continually growing, from an average estimated direct loss of US$5 Billion in 1981 to US$15 billion in 2011 (UNISDR, 2013).

Earthquakes and tsunamis cause on average the highest impact, both financially and in loss of life. Montz et al. (2017) compared the impacts of various natural disasters between 2003 to 2012 and showed that earthquakes and tsunamis on average generated damage of US$1.7 billion. Also, it cost the lives of 2,407 people (Daniell et al., 2010).

In 2010-2011, Christchurch in New Zealand met with a similar fate. Christchurch was severely affected by the Canterbury earthquake sequence in 2010-2011, including a magnitude (Mw) of 7.1 in 4th of September 2010, Mw=6.3 in 22nd of February 2011, Mw=6.0 in 13th of June 2011, Mw=5.8 in 23rd of December 2011 and thousands of the associated aftershocks (Geonet, 2011). Figure 1.1 shows the Canterbury earthquakes sequence from the 4th of September 2010 to the 1st of January 2012, which explains the volume of the disaster.

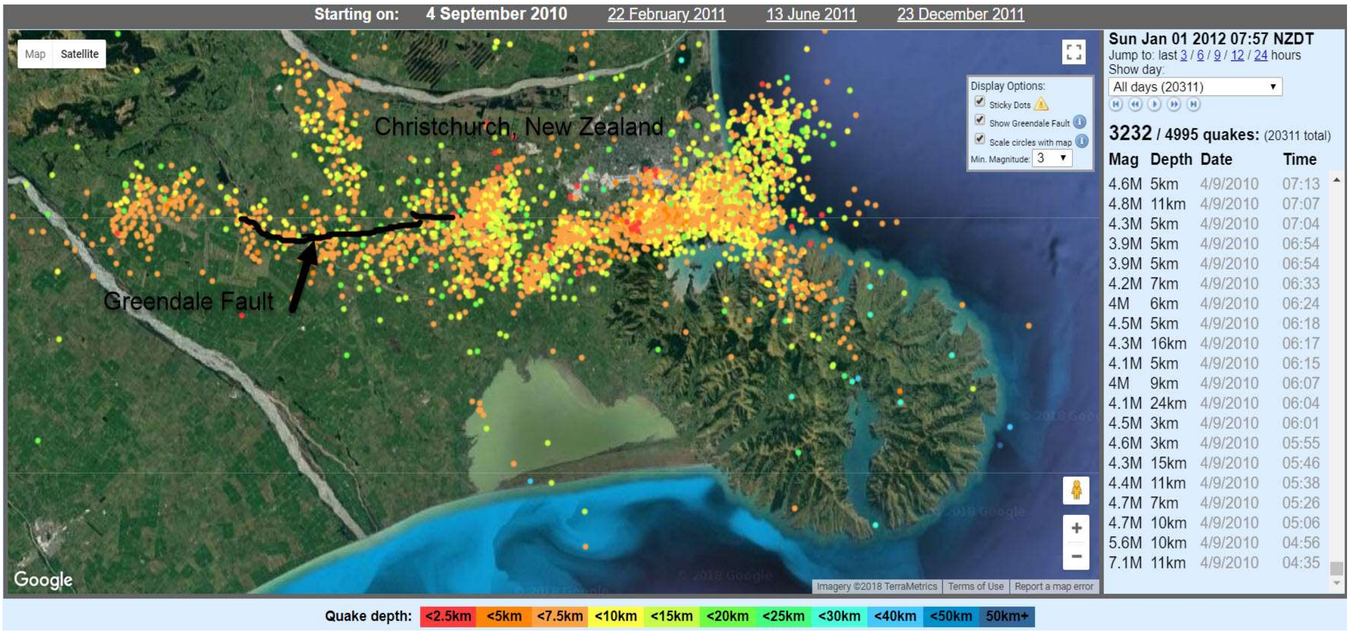


Figure 1.1: The Canterbury earthquake sequence from the 4th of September 2010 to the 2nd of January 2012 for earthquakes with a Magnitude larger than 3, adopted from (Christchurch Quake Map Website, 2018).

The Christchurch central business district suffered extensive damage, but also the wider area was hit. The disaster hit both residential and commercial buildings and infrastructure networks. The more massive earthquakes set off liquefaction of the soil in many urban areas, which caused severe damage to the horizontal infrastructure. The damage to the roads, potable water, wastewater, and stormwater networks was extensive (Giovinazzi et al., 2011; Stevenson, 2014). The initially estimated damage for the horizontal infrastructure surpassed 980 Km of damaged roads, 228 damaged bridges and 685Km of damaged wastewater pipes besides 850,000 tons of liquefaction need to be managed (Howes & Cheesebrough, 2013). Parker & Steenkamp, (2012) reported that the rebuild costs would be around NZ$20 billion (US$15 billion) excluding disruption costs, or 10% of GDP, which caused a significant crisis between the New Zealand government and insurance companies of how the rebuild should be funded.

According to Banaitiene and Banaitis (2012), big crises need better cooperation. These new 'mega-risks' (OECD, 2006) need new partnerships between the public and private sectors at all levels. UN Secretary-General Ban Ki-moon stated at the launch of the 2013 report that good partnership with the private sector is important to reduce economic losses after disasters (UNISDR, 2013). According to Baubion (2013), any disaster is a test to government capabilities to provide appropriate responses at the right time in order to protect the people and the businesses. It is a key responsibility to the government to find new innovative crisis management responses to avoid the effects of natural disasters and working towards disaster risk reduction and the total recovery programmes. As a part of responding to the earthquakes of 2010 and 2011 in Canterbury, the New Zealand government established special recovery organisations, the Canterbury Earthquake Recovery Authority (CERA), a central agency responsible for acting on behalf of the Central Government concerning Earthquake matters, and directing the recovery strategy (CERA website, 2012). It created the Stronger Christchurch Infrastructure Rebuild Team (SCIRT), an alliance which took the responsibility of rebuilding the horizontal infrastructure in Christchurch (De Vries et al., 2015). The Fletcher Earthquake Recovery (EQR) was established to manage the residential repair programme on behalf of the Earthquake Commission (EQC) (EQC, 2012).

1.3 SCIRT as a unique and complex Post-Disaster Recovery System

Da Silva (2010) described the post-disaster reconstruction as a complex process that requires multi-sectoral involvement, very significant resources and a wide range of skills. SCIRT was a unique and complex alliance as it was designed to have both competitive and collaborative mechanisms operating concurrently (The Controller General of New Zealand, 2017). SCIRT was unique due to the large number of projects, the extent of the damage, the number of stakeholders, the organisation of the team and the dynamic type of risks that they needed to manage during the recovery (Noktehdan, 2017). SCIRT was an example of the cooperation between the public and the private sector to execute a recovery programme after a disaster. The SCIRT owner participants are the Christchurch City Council, CERA, and the New Zealand Transport Agency (NZTA). The non-owner participants are contractors; City Care (CC), Downer (DN), Fletcher (FL), Fulton Hogan (FH), and McConnell Dowell (MD), see Figure 1.2 (SCIRT, 2012). All other experts, like the design and asset management consultants, were engaged later in the programme. The reason that design organisations were not part of SCIRT was to reduce the total number of organisations involved in the programme. However, staff had been hired by the alliance from thirteen different design organisations to undertake the design for the programme. Furthermore, a wide pool of professionals and experts were engaged, the five contractors were permitted to contract out a certain amount of work to local subcontractors.

The management in SCIRT consisted of three levels, which are Client level, SCIRT level, and Project Delivery level. Each level embraced a specific type of risk management; for the client, it was Strategic Risk Management (SRM); for SCIRT, it was programme or Enterprise Risk Management (ERM); and for delivery teams, it was Project Risk Management (PRM). (See Figure 1.2). More details on these three levels of risk management is covered in the literature review chapter.

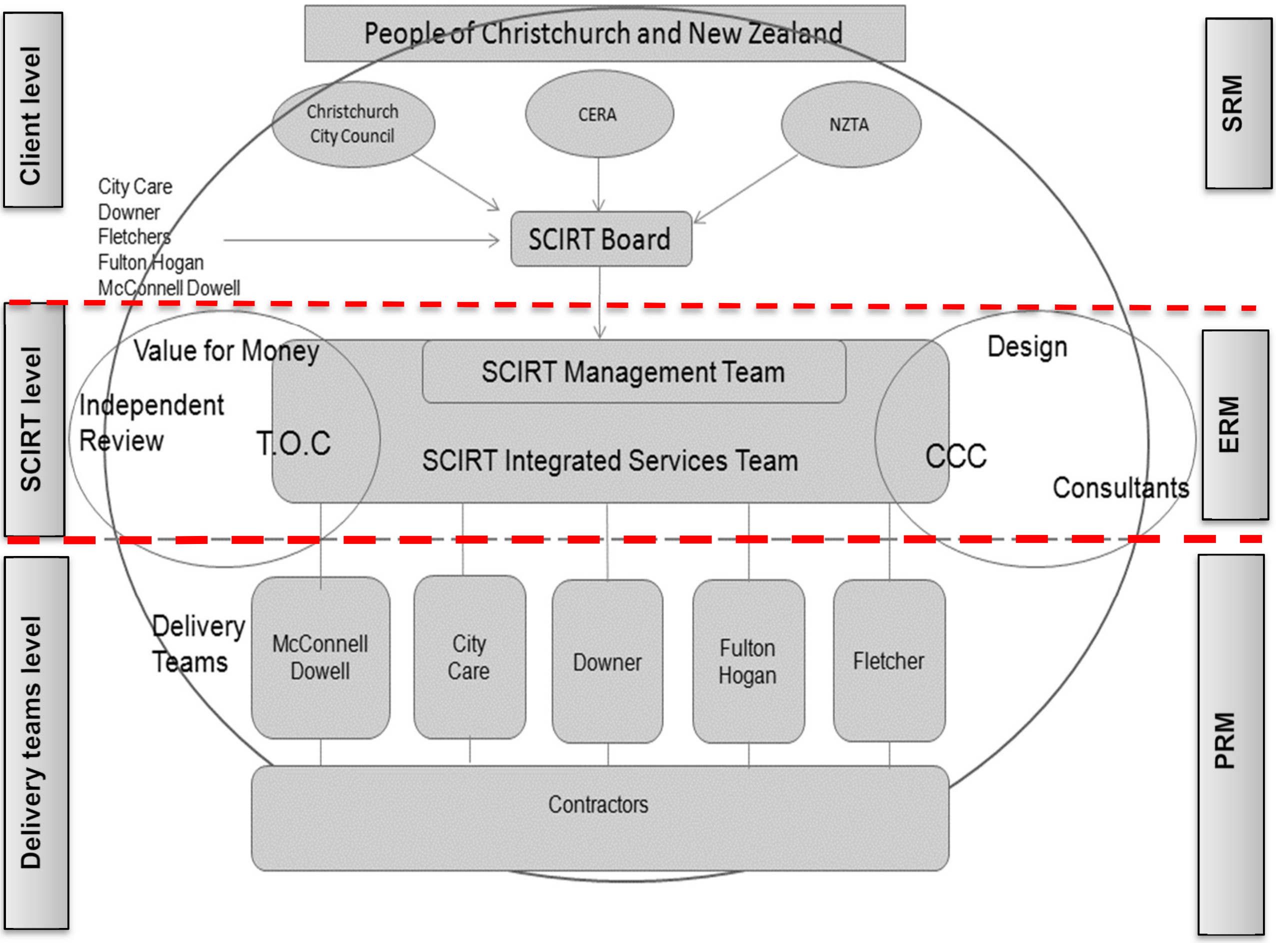


Figure 1.2: SCIRT alliance and the different level of risk management (adopted from SCIRT website, 2012).

Moreover, due to the emergency situation and the time limitation, most of the project life cycles overlapped in SCIRT programme; project definition, concept design, detailed design, project constructions and handing over stages, were happening concurrently, which added to the complexity of this recovery system.

SCIRT was an alliance between owner participants and non-owner participants, an alliance that worked well (Botha & Scheepbouwer, 2015). SCIRT alliance has proved to be a good platform for concurrent management levels from client, design and construction companies to work at the same time, which was useful in dealing with the complexity of the situation (SCIRT, 2016). There was a lot of information and data available inside SCIRT with hundreds of infrastructure projects. The total initial estimated cost of SCIRT programme of projects was $2.94 Billion (De Vries et al., 2015). It provided an opportunity for exploration and analysis of the interaction between the management levels. With the large number of stakeholders involved, SCIRT can be described as a complex post-disaster recovery system, which emphasised the need to find proper system analysis approaches to break down this complexity. That led to choosing System Thinking (ST) and System Dynamics (SD) in conjunction with different analysis methods to investigate the case study. This will be explained in more detail in Chapter 3, the research methods.

1.4 The Study Motivation

Although there is extensive literature about risk management in the construction industry (Banaitiene & Banaitis, 2012; Cagliano et al., 2015; Liu et al., 2013; Mustafa & Al-Bahar, 1991; Marsh Risk Consulting, 2012; Lam, 2003; Olson & Wu, 2008; Rittenberg & Martens, 2014; Zhao et al., 2014), these studies did not investigate the differences of pre- and post-disaster reconstruction projects. The response could vary between countries as the geographical influence on management and on how to handle risks can be affected by cultural beliefs (PMI, 2013). Wang (2010) identified specific areas that need further investigations in risk management in post-disaster. These areas included new managerial principles, innovative safety cultural changes, novel army preparedness for a regime, development of advanced practice for safety, consideration of age issues in equipment that was utilised, and advanced procurement strategies. According to UN (2015), there is a gap for studies presenting an investigation of risk management inside companies or organisations implementing or executing recovery projects in the construction industry.

Construction companies have risk management procedures optimised for BAU circumstances. And according to Blockley (2013), there is a need to develop a guidance tool to manage different risks in projects under varying conditions, using different types of data. There is a gap in research concerning risk management procedures in post-disaster recovery systems. Studying the risk management practices before and after disasters in construction projects is of high importance to not only the private sector but also the public sector.

1.5 Research Aims and Objectives

The literature review of this study highlighted several gaps related to investigating risk management in post-disaster recovery systems. These gaps are, previous studies did not recognise the differences between Traditional Risk Management (TRM) and PDRM, and there were no studies found that investigated the differences between TRM and PDRM. In addition, there was no evidence of dedicated studies that investigated post-disaster recovery systems as a whole from the risk management perspective by looking through all the attributes that influence risk management in these systems. Nevertheless, there were no studies found that investigated the different layers of risk management (SRM, ERM, and PRM) in post-disaster recovery systems or investigated the critical risks and the dynamics of these risks between the different levels of risk management.

Based on the initial investigations of this study (which are covered in more detailed in Chapter 4, the research validation), BAU, including TRM practices, which are usually adopted by the construction industry, proved at times inadequate to deal with recovery projects. Nevertheless, although risk management had previously caught the attention of many researchers (including investigating the sources of the risks and how to manage it), there is a gap in studying practical cases from real-life of studying risk management in post-disaster recovery systems as a whole. A post-disaster recovery system Case study that could be used to develop a proper guideline could be followed in the future for similar situations.

The primary aim of this research is to investigate risk management practices in post-disaster recovery systems in the construction sector using ST, and SD approaches to develop a PDRM model that could be used as a risk management guideline in similar situations in the future. The PDRM model meant to fulfil the gaps where the TRM falls short for recovery projects. Moreover, the following objectives were developed in the initial investigation of this research, which represented the first step in System Theory Methods (STMs) to identify the problems and the opportunities using initial interviews and brainstorming session; (Chapter 4 and Chapter 6)

- What are the critical risks in the three risk management levels (SRM, ERM, and PRM)?
- What are the interactions and the dynamics between risks in the three levels (SRM, ERM, and PRM)?
- What are the Critical Success Factors (CSFs) for effective PDRM?

1.6 The Research Methods

This research used SCIRT as a case study to investigate the risk management in recovery systems. The data is collected using both qualitative and quantitative approaches. The quantitative approach, involving a survey, and the qualitative approach, involving interviews, have been conducted with risk and construction staff from the SCIRT programme. The study adopted ST as an overarching approach to investigate recovery systems as a whole, SD was used to develop the outcomes, and different analysis methods to target a specific area of investigations (Figure 1.3).

In recent research, ST and SD have been used as a way to address complex problems and practices. Senge (1990) defined ST as a framework that is used to investigate relations rather than things, to see patterns rather than random, and to connect wholes rather than separate parts. According to Radzicki & Taylor (2008), SD is an approach using mathematical methods and modelling techniques to understand and frame complex and nonlinear behaviours, issues and problems.

ST, for decades, has been considered to be an effective approach to study complex systems as a whole. Also, SD used to understand and represent this complexity and changes over time, which has been recommended for further research by several researchers such as Dangerfield et al. (2014). In this research, we were dealing with a complex post-disaster recovery system represented by SCIRT as a case study. Besides, ST and SD provide an integrated way of analysing system procedures, people, performance and the surrounding environment. The case study "SCIRT" was complex and dynamic, with a large number of stakeholders. Therefore, it is beneficial to consider an approach that investigates the system as a whole; to look through all the attributes and factors that influence and drive this complex system. In addition, to use approaches that maximise the outcomes, and minimise the influence of unpremeditated consequences and aligning the interest with reasonable management of risks and opportunities and provide an immediate test for system behaviours using general observations (Godfrey & Sillitto, 2015).

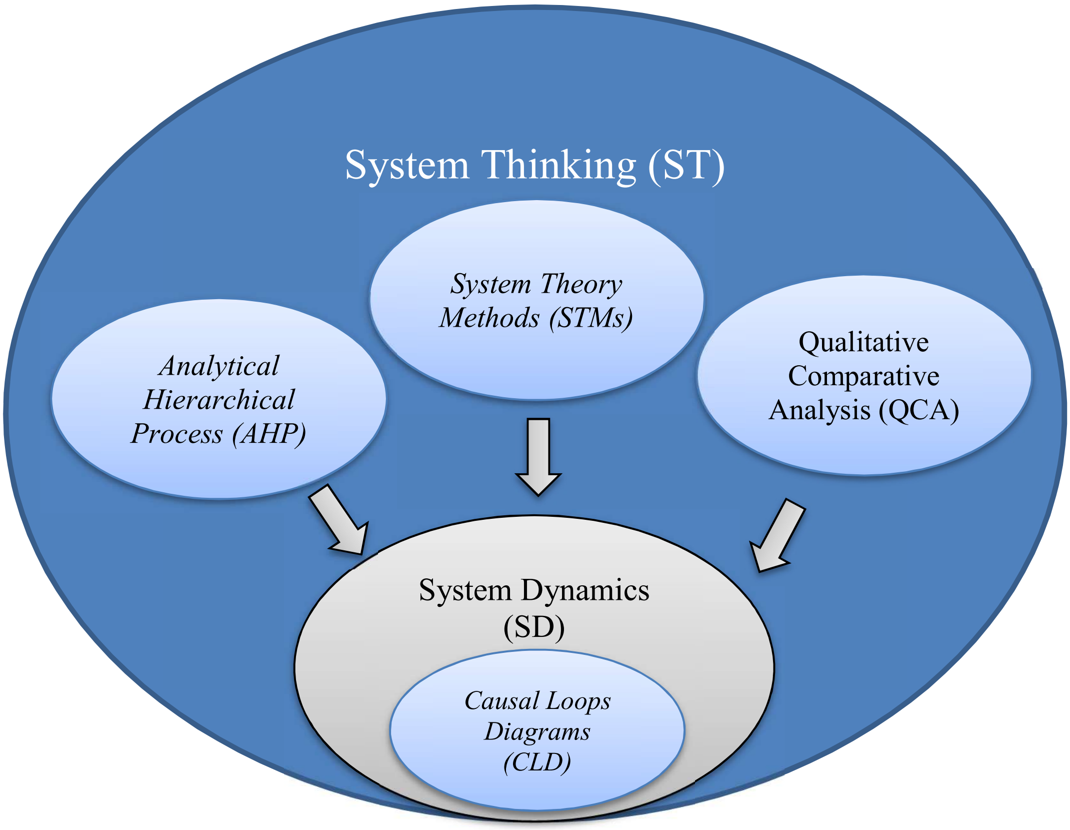


Figure 1.3: Holistic view of the research methods.

Figure 1.3 gives us a holistic picture of the main research methods in this study. ST represents the overarching approach to investigate post-disaster recovery systems as a whole. SD used to visualise the outcomes of this research represented by its tool, Causal Loops Diagrams (CLD), to simulate the dynamics and the important parts that influence risk management inside post-disaster recovery systems. Different analysis methods used to investigate specific areas inside the system which are, Analytical Hierarchical Process (AHP) to investigate the critical risks inside the system, STMs to investigate the dynamics between these risks, and Qualitative Comparative Analysis (QCA) to investigate the CSFs of effective PDRM inside the system. More details of the methodology and each method is provided in Chapter 2 and Chapter 3.

The diversity of analysis methods provides an integrated way of analysis, maximises the outcomes and minimises the influence of accident consequences. More details about the analysis methods are available in the methods chapter (3), and more details on why post-disaster recovery systems are considered to be different from the risk management perspective are represented in the validation chapter (4).

1.7 Structure of the Dissertation

The following section explains each chapter structure and gives a brief of each chapter contents.

Chapter 2 represents the analysis of the previous studies and available knowledge in risk management library through a comprehensive literature review to identify the gaps in the research market.

Chapter 3 presents the methods adopted in this study including a brief of the approach used for data collection and data analysis. It also presents both the theoretical and conceptual frameworks, ethical considerations, and research constraints.

Chapter 4 represents the first step in the ST approach. It was used to investigate the recovery system case study to discover the opportunities and the problems and develop the research questions. Also, it was used to validate the point of research by clarifying the differences between TRM and PDRM and were summarised in Table 4.2.

Chapter 5 investigates and ranked the critical risks between the different management levels in recovery systems.

Chapter 6 explores the Critical Success Factors (CSFs) for better risk management and the relation between the variables in the recovery systems.

Chapter 7 examines the interaction of risks between the different management levels in the case study.

Chapter 8 visualises the data using SD tool, Causal Loops Diagrams (CLD), to develop the PDRM model.

Chapter 9 presents and discusses the findings, conclusions and recommendations.

1.8 Positioning of the Study

The research is positioned in the field of risk management, specifically in post-disaster recovery systems. Despite the available studies of risk management in construction for TRM and PDRM, there were no specific studies found that recognised the differences between TRM and PDRM (Chapter 2). The study investigated the risk management inside post-disaster recovery systems from a more integrated perspective using ST and SD to produce a PDRM model that can be used as a guideline for similar situations. Senior professionals and decision makers can use this guide in the construction industry for more effective risk management in recovery projects.

Chapter 2: Literature Review

2.1 Introduction

Risk is an unavoidable part of a construction project's lifecycle. Infrastructure and construction projects are unique, and risks arise from several different sources. Construction projects are inherently complex, dynamic, and involve multiple processes and interact with many industries (Hlaing et al., 2008) while creating products that are vulnerable to natural disasters. Many participants as individuals or organisations are actively involved in the construction project, and their interests and expectations from any project may not necessarily be the same and can be influenced by both internal and external factors during the project execution or even after project completion, which adds to the complexity of these projects (Blockley, 2013; Olson & Wu, 2008).

The chapter explains the complexity of the construction industry after a disaster and reviews risk management interaction between the different levels of management. Samples of available models of Risk Management Maturity (RMM) and the gap in PDRM research will be highlighted. Towards the end of the chapter, a review of ST and SD in risk management and the used analysis methods will be illustrated.

2.2 Traditional Risk Management and Disaster Risk Management in the Construction Industry

Since the 1990s, there has been an increased interest in risk management in the construction industry. It is recognised that the management of risk must be emphasised in the projects at each level regardless of the size or the objectives of the projects to be achieved (Hwang et al., 2013).

As a response to the need for a consistently recognised risk management practices and processes, the International Organisation for Standardisation (ISO), has created a family of standards called ISO 31000; which are ISO 31000:2018 (Principles and Guidelines on Implementation), ISO/IEC 31010:2009 (Risk Assessment Techniques), and ISO 73:2009 (Risk Management Vocabulary) (ISO official website, 2018). ISO 31000:2018 is well known as the universal base to provide a structural guideline to all risk management practices in any organisation before, during or after a disaster. This guideline covers three major areas, which are, principles, framework, and process of risk management, as shown in Figure 2.1.

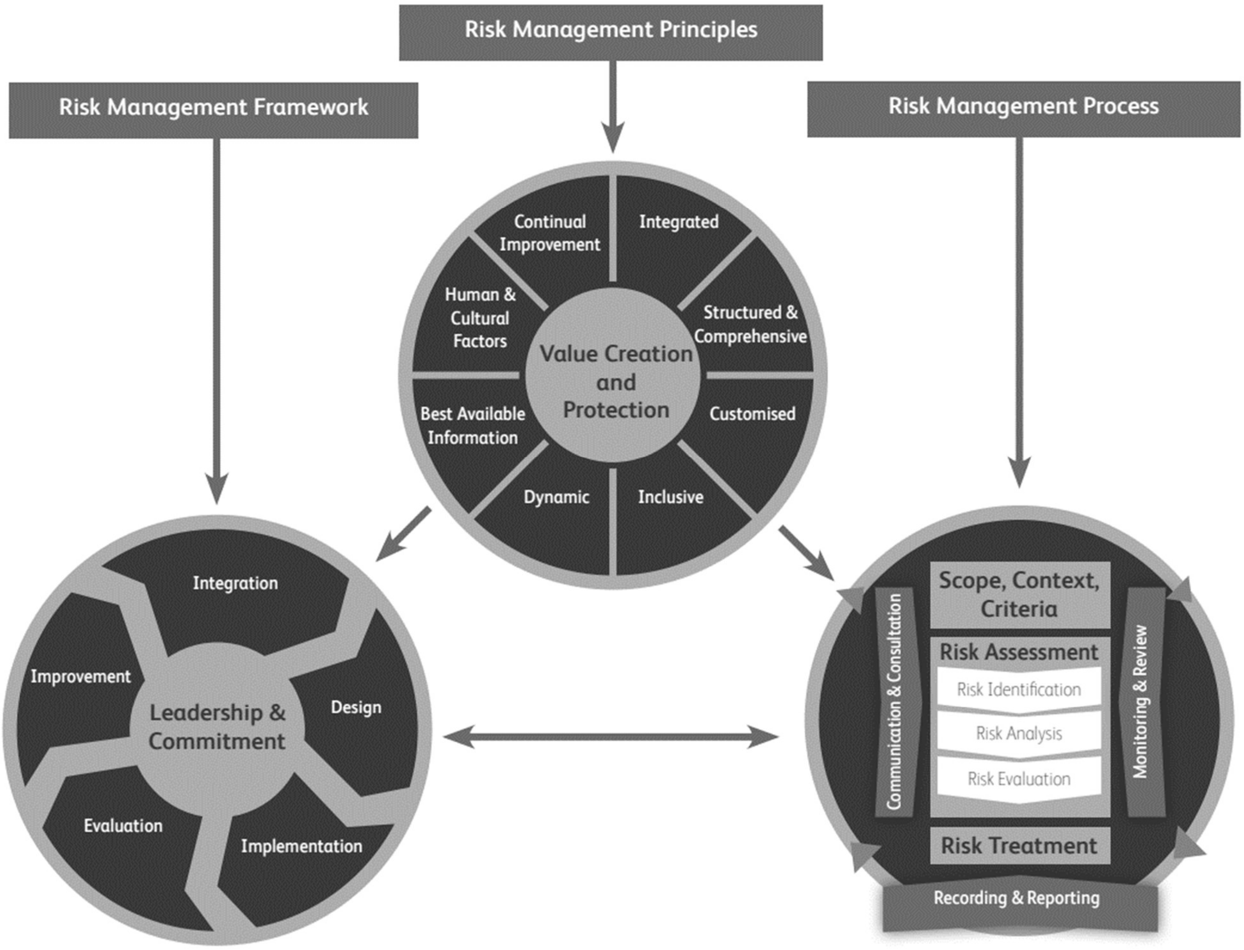


Figure 2.1: Relationships between principles, framework and process of risk management in ISO 31000:2018.

(ISO official website, 2018)

The following sections give a scan over some of the available studies in the risk management and some examples of the models available for more effective risk management before, during and after a disaster.

2.2.1 Traditional Risk Management

TRM has been used in several risk management books and studies as the ISO 31000 framework and process. For instance, in the Health Services sector, the Australian government uses the TRM framework and process ISO 31000 as the base for the NSW Health Disaster Risk Management Guidelines (Counter Disaster Unit, NSW, 2011). Moreover, Shaw & Theobald (2011) mentioned that there are some risks related to resilience that have not been recognised within the TRM framework and process. Yu et al. (2017) suggested that it is beneficial to use social network analysis to manage stakeholder-associated risks in TRM. Dojutrek et al. (2016) checked the overall TRM framework and process and recommended a security-related measure could be used in the evaluation of transportation and infrastructure projects.

TRM in the construction industry was an area of interest and a subject for further investigation in the last decade (UN, 2015). In these studies, most researchers focused on building risk management frameworks and models in BAU conditions. Researchers used frameworks to study aspects of risk management in a structured manner or used a model to present the system they were investigating in a schematic form.

Examples of studies that focused on building risk management models in BAU conditions between different management levels are: Liu et al. (2013) investigated the relation between PRM and ERM. They found that PRM could be improved by controlling project risks at the enterprise level through four elements, which are cooperative culture, external service, risk management procedure, and risk management department. Molenaar et al. (2010) developed guidelines for risk analysis tools and management practices to control transportation project costs. Osipova and Eriksson (2013) investigated the balancing control and flexibility in joint risk management in construction projects. Zou et al. (2010) developed a model for construction organisations to improve risk management capability. Adams (2008) identified some of the available risk techniques in TRM as follows: Synectics, expert interviews, and pondering for risk identification; relative frequency, scaled assessments, or subjective probability for risk likelihood and risk influence, decision tree, fault tree, event tree, sensitivity, or scenario analyses for risk analysis.

The common levels of TRM in the academic library could be categorised into three main areas; SRM, ERM, and PRM. Besides these areas, there are studies dedicated to developing RMM models to increase risk management performance. The following section gives a brief of some of these models.

2.2.1.1 Project Risk Management

According to the Project Management Institute (PMI, 2012), risk management in projects is one of the ten project management knowledge areas. Risk management process contains risk planning, risk identification, qualitative risk analysis, quantitative risk analysis, risk response planning, and risk monitoring and controlling (PMI, 2013). The risk management process is vital for achieving success in the project and for meeting the desired objectives in terms of time, cost, quality safety and environmental trends. In general, there are four main strategies in terms of treating risks in order to control their consequences in construction; risk avoidance, risk transfer, risk reduction and risk acceptance (Perera et al., 2009).

One of the most common approaches in PRM is the Australia and New Zealand Risk Management Model (AS/NZS ISO 31000, 2009). According to this, the risk management process should include the following five major activities, establishing the context, identifying risks, analysing risks, evaluating risks, and treating risks. These activities must be embedded with effective communication, consultation, and monitoring and review of activities.

PRM has caught many researchers' attention. Liu et al. (2013) explained that project success could commonly be an attribute of the integration between PRM and ERM. One of the noteworthy approaches in risk management in the project level is the scalable approach "Caltrans project risk management", which was developed by the California Department of Transportation (Molenaar et al., 2010). The approach includes six steps, which are covered by scalable project risk-management elements where the projects are categorised by size, complexity, and effective communication.

Although many studies have covered the PRM area in general, there were no specific studies found on PRM and the dynamics between the other risk management levels in recovery projects.

2.2.1.2 Enterprise Risk Management

COSO (2017) defined ERM as the procedure prompted inside the organisation by its board of directors, top management or other employees, in a strategic level, to identify possible events that may affect the organisation and find ways to manage and reduce the risks related to this event to be within the organisation risk appetite. According to Aven (2013), the organisation risk appetite is the level of risk the organisation is willing to take in order to achieve its strategic objectives.

An example of investigating a case study to develop a risk management model for construction projects is Osipova & Eriksson did a study in 2013. Osipova & Eriksson (2013) created a model called Joint Risk Management (JPM). The model is a dynamic approach to risk management, including identification, assessment and response to the risks based on proactive and joint management throughout the project lifecycle. The research methodology of their study followed a case study approach as the core of the investigation. Authors chose two case studies, the construction of a new medicinal laboratory, and the construction of a Hydro Plant station for a large public organisation. The key finding of this research showed that JRM required a balanced combination of controlling tools to manage risk in the project level and flexibility to realise the unexpected events at the enterprise level. Moreover, regarding JRM in the implementation of construction projects, the authors argued that it is important to manage the tension between control and flexibility. They started the study by offering a theoretical outline to identify the correlation between flexibility-oriented and control-oriented systems, followed by presenting the connection between control and flexibility in risk management.

According to Geraldi (2008), flexibility in organisations is based on specific questions including "what", to identify the contract flexibility, "how", to identify the tools and instrument, "who", to identify the human resource, "when", to identify the schedule and "where", to identify the location flexibility. Answering these questions is the path to find a balance between control and flexibility in the management of projects in the multi-projects firms in general, which could benefit the risk management as being a part of the overall project management areas of knowledge.

Although many studies have covered the ERM area in general, there were no specific studies found on ERM and the dynamics between the other risk management levels in recovery projects.

2.2.1.3 Strategic Risk Management

SRM is focused on the key risks that affect shareholder objectives and values (Iverson, 2013). COSO (2017) clarified strategic objectives as the core of the organisation strategy, and it is representing the top goals associated with supporting the organisation mission and vision. Consequently, strategic risks could be defined as any risks associated with internal or external events that could prevent the organisation from achieving its strategic objectives (Iverson, 2013).

An example of a study in SRM was done by Rueda-Benavides & Gransberg (2016) to investigate the risk management strategies that could be used in the client level, represented by public transportation agencies, for more effective risk management in Indefinite Delivery/Indefinite Quantity (IDIQ) contracts. The study proposed a framework for an IDIQ contract risk analysis process to mitigate, avoid, or transfer the risks associated with nine unfavourable situations in the procurement approach.

In a disaster situation, there are many stakeholders, and this always drives the risk profile. The risks are not only related to the disaster, the physical and intense occurrence of the phenomenon but also with the conditions that facilitate or favour the vulnerability of such events when it occurs (Nguyen & Yuansheng, 2012). The vulnerability is closely linked with the social process in the areas that are prone to disasters. It is also usually related to the lack of resilience, susceptibility and fragility of the population at the time of facing these hazards. Hence, it can be identified that disasters are socio-environmental in nature. As a result, reducing them in recovery projects should be part of structured decision-making. This must not only be followed for the post-disaster reconstructions, but the development planning and public policies must be formulated in the first place following these measures (Nguyen & Yuansheng, 2012).

The link between the three levels of risk management is vital for more integrated outcomes. One of the valuable lessons learned after the global financial crisis is that organisations need to have a clear link between the strategy and risk management and be able to identify and manage risk in a highly uncertain environment (Frigo & Anderson, 2011). Hence, it is important to track these levels of risk management maturity.

The following section highlights the previous studies that were undertaken to develop different risk management models to measure and improve the RMM in organisations. These samples of models were the motivation to develop a similar model for post-disaster recovery system in this study.

2.2.1.4 Risk Management Maturity

RMM could be referred to as the assessment procedures used to define the current capability of an identity or organisation to manage risks and find ways towards improving risk management inside it (Hillson, 2012). One of the related topics of RMM is covered by a study done by Zhao et al. (2014). The authors investigated the degree of Enterprise Risk Management (ERM) maturity in Chinese Construction Firms (CCFs) based in Singapore. Three case studies have been assigned to support the research besides a survey with 35 CCFs occurred to collect data related to carrying out

ERM, taking into consideration choosing various size ranges of firms. The research showed a low level of ERM maturity in these organisations that was positively correlated with the firm size.

Another study by Zhao et al. (2013), they established what they called a Fuzzy Enterprise Risk Management Maturity Model, which included 16 core ERM maturity criteria with 66 best practices. The study showed a lack of applying information technology and Key Risk Indicators (KRIs), which needed attention from the management board. It also showed that the bigger the firm, the higher the level of engagement with ERM; although, the size of the firm did not influence the ERM procedure. Furthermore, the awareness of some of the bigger companies was influenced by their mother firms overseas, as they had to comply directly with parent firm's requirements or indirectly by regulatory requirements, which confirm that larger size companies are more embedded to risk management practices. Small to medium companies did not have a similarly high level of requirements to implement ERM. Authors argued that in construction companies, ERM and PRM are often entangled and overlapped.

Another interesting study was done by Jia et al. (2013), where they discussed measuring RMM in large-scale construction projects such as airports, skyscrapers, and rail networks. The study proposed a system for RMM for these types of projects based on three functional components, which were capabilities, evaluation and evolution and tried to integrate it with the available theories in engineering systems. The authors investigated some of the available recent risk-management maturity models as follows:

- Office of Government Commerce (OGC) Model, which is based on generic risk management and is proactive across sectors driven by five maturity levels, initial, repeatable, defined, managed and optimised. These levels are structured by organisation context and objectives, reinforced structure, stakeholder involvement, roles and responsibilities, supportive culture, overwhelming obstacles, early warning indicators, reporting, review cycle and continuous improvement (OGC, 2007).
- MMGRseg model for the ICT (Information and Communication Technologies) sector with five maturity levels, including initial, known, standardised, managed, and optimised levels. These levels are set up by risk context definition, risk analysis and assessment, risk treatment, risk acceptance, risk communication, risk monitoring and analysis. (Mayer & Fagundes, 2009)

• The RM3 model is specifically for the construction sector, which includes management and leadership capabilities concerning risks, organisation risk management culture, identifying risk, analysing risks, and developing an application of standardised risk management process. These are driven by initial and ad hoc, repeating, managing and optimising maturity levels (Zou et al., 2010).

Zou et al. (2010) developed a hybrid application system called Risk Management Maturity System (RMMS) by integrating the available theories into to enable an effective working system. The development aimed to improve the risk management maturity and project management inside construction companies. It allows the main contractors in mega construction projects to understand the current status of their risks better. Figure 2.2 shows the proposed RMMS for large-scale construction projects. Zou et al. (2010) used the Beta Construction Company's airport project as a case study for investigating the efficiency of RMMS and justifying the principles and methodology. They measured it against the PMI OPM3 and ISO 31000:2009 standards. The authors found that the company needed to make a plan to improve the risk management maturity levels.

Jia et al. (2013) compared the above models under the same theme using weight evaluating method to the RMMS with a two-stage process to cover both the Risk Project Management (RPM) and Organisation Management (OM). They found that structure optimisation of both the RPM and OM is the core of better RMM in large construction companies. Moreover, the study highlighted the benefits of using the RMMS to help construction companies to adapt to emergencies from the external environment and to improve the risk management capabilities inside these organisations.

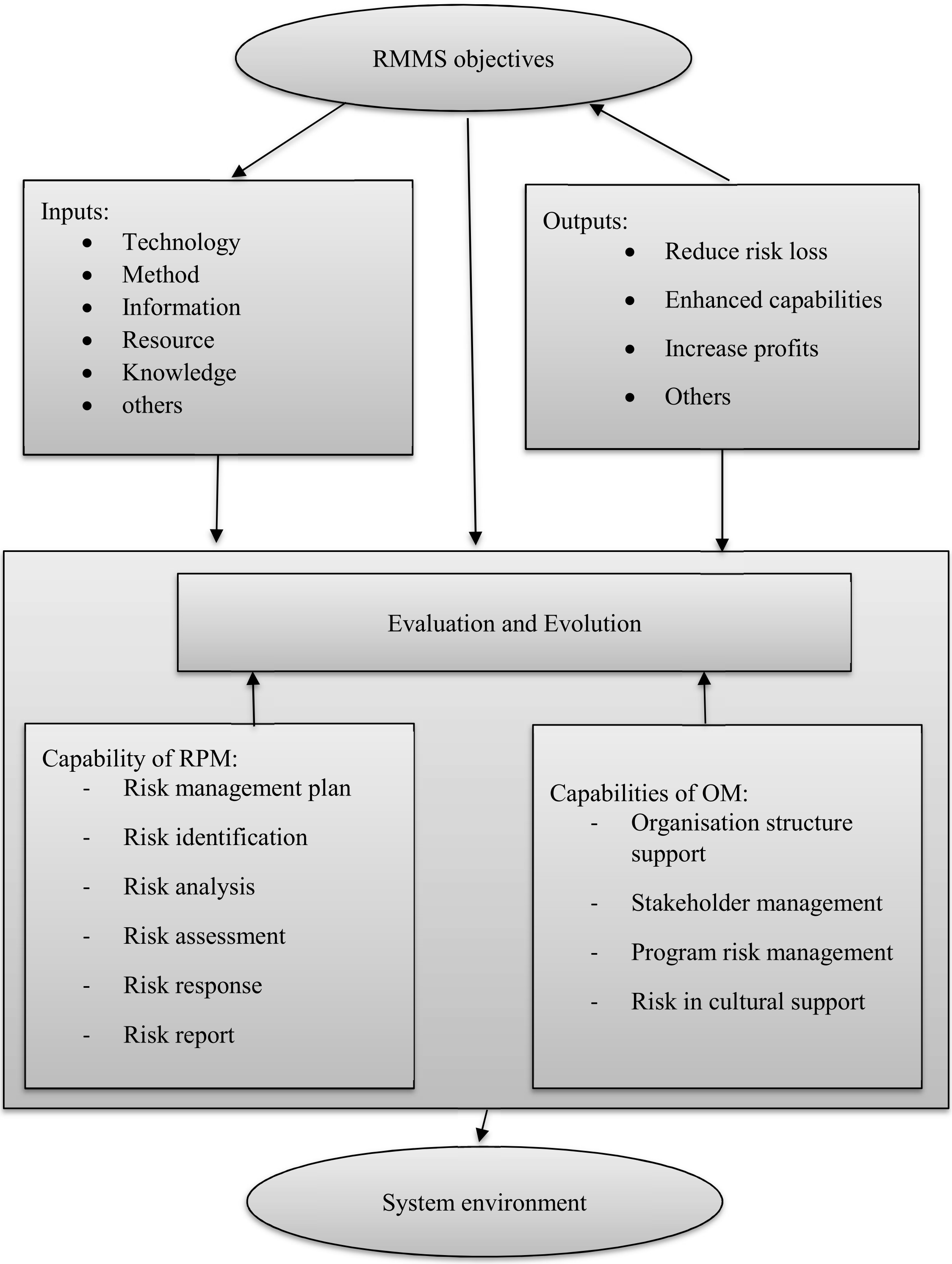


Figure 2.2: Risk Management Maturity System framework (Jia et al., 2013).

2.2.2 Disaster Risk Management

According to ERSA (2014), Disaster Risk Management (DRM) practices are the essential condition for community safety, sustainability and resilience. Therefore, the process of analysing and assessing the risks in DRM needs to be undertaken in a consistent and science-based manner for delivering the information needed to improve decision-making before, during and after a disaster.

Good progression was made by Australia to deal with different types of natural disasters such as fires and floods by developing several strategies and frameworks in DRM. For example, Queensland emergency services developed a framework to manage disasters, which is named Queensland Disaster Management Arrangements. QDMA includes the Queensland Disaster Management Strategic Policy Statement, Queensland State Disaster Management Plan, and Queensland Emergency Risk Management Framework (QLD, 2016, Arklay, 2012). The statement is to keep people safe and make communities more resilient to disaster risks and impacts. While QDMP includes structure and governance, risk assessment, prevention, preparedness, response, and recovery. It contains the guiding principles and objectives of the Disaster Management Act 2003. QERMF consists of four steps; establishing the context, analysing hazards, assessing risk, risk-based planning. The framework provides a risk assessment that can be used in disaster management planning.

2.2.2.1 Risk Management in Recovery Projects

When it comes to reducing the impact of disasters, the prevailing trend is on finding solutions and strategies to manage disaster risks. Those include actions and activities applicable to pre-impact, as well as recovery or reconstruction stages with an expectation of new disaster risk conditions or situations. A strong relationship was identified between disaster risk and disaster risk reduction, and development and planning stages (Lavell, 2003, 2009; UNDP, 2004; Van Niekerk, 2007; UNISDR, 2009, 2011; Dulal et al., 2009; Wisner, 2011; Palliyaguru et al., 2014).

Chang et al. (2012) explored the critical factors that affect resource availability in recovery projects. The study used case studies and a triangulation method to investigate the resource availability around Indonesia, China and Australia during their recovery procedure from natural disasters. After they compared and examined the differences between the three markets, they found that specific cultural factors; socio-economic environmental and political elements influenced the resource problems and the adopted solutions. The study indicated that resource availability needs to be managed in recovery projects.

Ophiyandri et al. (2013) stated that every post-disaster reconstruction project is unique as it involves additional factors that could influence risk management procedures, which not there in BAU situations or normal environment and contractor-based methods such as the stress on the government capacity and funding availability to handle the expectations from both the community and the media. Ophiyandri et al. (2013) assessed the implementation of a community-based Post-Disaster Housing Reconstruction Project after earthquake and tsunami in Indonesia. They highlighted the twenty most significant risks to the government. Those include lack of local government support, unclear reconstruction policies, problems related to communication and coordination, lack of funding and knowledge of the funder. Prieto and Whitaker (2011) investigated how engineering and construction methodologies change in recovery projects and how post-disaster logistics affect construction activities. They stated that in traditional circumstances, the projects focus on creating new permanent facilities; however, in recovery projects might have a broader range of temporary works to secure the sites. Social dimensions, including sustainability, become part of the overall disaster recovery process, which may also affect the projects post-disaster output (Chang et al., 2010).

Mannakkara (2014) explored post-disaster reconstruction in Sri Lanka and Australia and created a framework for building better based on risk reduction, community recovery, implementation and monitoring and evaluation. He mentioned six principles for his framework, which are: improvement of, structural designs, land use planning, social recovery, economic recovery, managing stakeholders, and legislation and regulation. Shafique (2016) investigated the post-disaster reconstruction from the community perspective. He highlighted the importance of community as a key stakeholder and how they can be driving the view of decision making in post-disaster. Da Silva (2010) explained that every post-disaster situation is unique, depends on the type of disaster and the characteristics of the country.

2.3 Defining the gap in the research market.

Beside the above-mentioned studies, some similar studies are, in PRM (Lyons & Skitmore, 2004; Subramanyan et al., 2012; Xiang et al., 2012; Goh et al., 2013); in ERM ((Manaba et al., 2012; Zhao et al., 2013; Lam, 2003); in SRM (Ammann, 2008; Rimbock & Loipersberger, 2013; Frigo & Anderson, 2011); and in DRM (Cardona & Carreño, 2011; Naoi et al., 2012; Altabbakh et al., 2013; Sobremisana & Pilar, 2014; Ahrens & Rudolph, 2006; Bosher et al., 2007; Box et al., 2013). After considerable investigation through the available studies in risk management, the studies could be grouped into three areas (Figure 2.3). The first area is TRM, that represents risk management procedures in BAU. TRM further distributed into SRM, ERM, and PRM. Under this category, many studies have been dedicated to creating different RMM models to provide guidance to improve the risk management systems inside the organisation.

The second area is Disaster Risk Management (DRM), which represents disaster-risk reduction procedures dealing with adverse impacts of natural hazards and improving preparation for responses to adverse hazard events (UNISDR, 2015).

The third area is the PDRM. In this area and based on the above literature review, there were no studies recognised the difference between TRM and PDRM. There was no evidence of studying post-disaster recovery systems previously as a whole system to endorse effective risk management in recovery projects through the three levels of risk management.

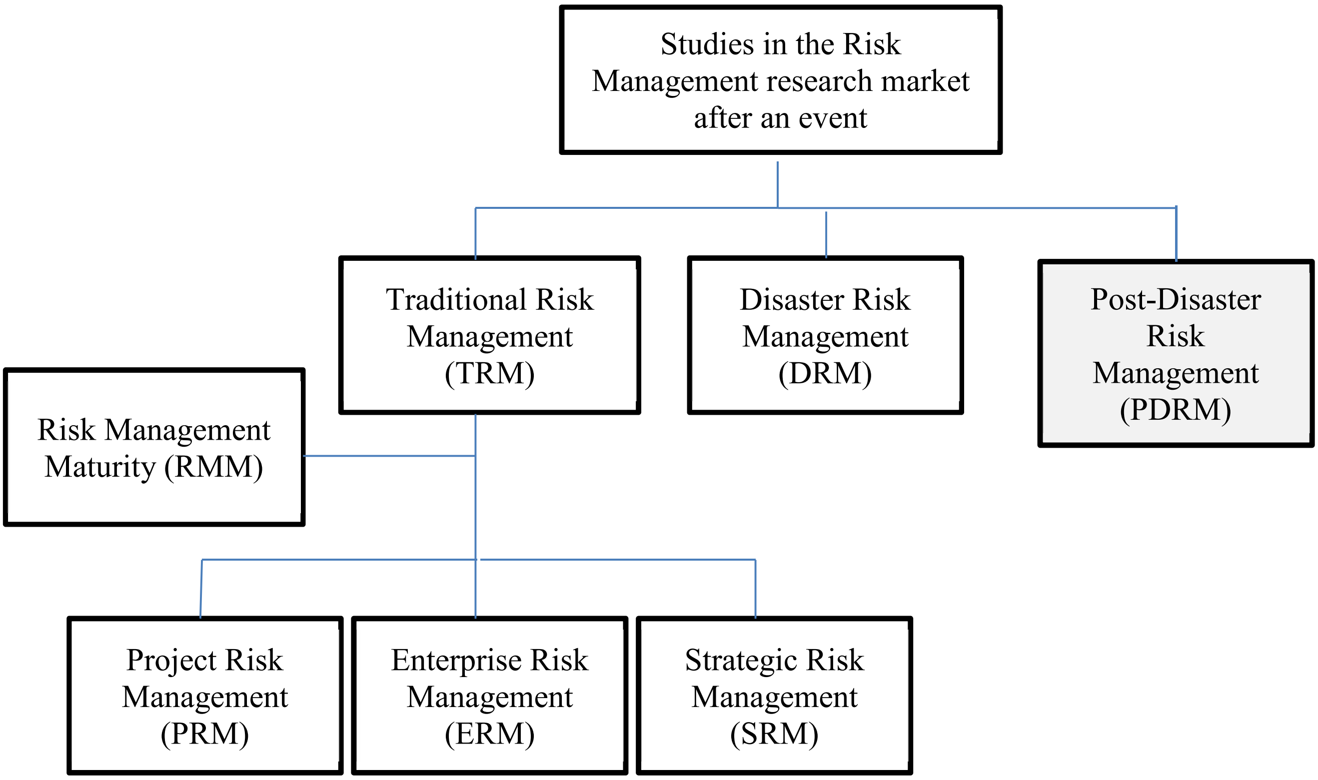


Figure 2.3: Chart of Literature Review categories in risk management after an event.

The above literature review highlighted several gaps. Most of the available studies used TRM as the base to manage risks in both BAU projects and recovery projects. There was substantial evidence that there is a lack of studies that are targeting recovery projects after a disaster in the construction industry. There were no studies found recognised the differences between TRM and PDRM. There were no studies found investigating the difference between the risk management procedures before, during and after a disaster. Most of the studies focused on analysing TRM; however, there was a lack of investigating risk management in recovery systems in particular (which is referred to in this study as PDRM). There was also strong evidence of studying risk management practices before a disaster in SRM, ERM, and PRM levels, but there was a shortage of studying the same levels in post-disaster recovery systems and investigating the dynamics between these levels. In addition, there was a lack of investigating recovery systems as a case study and studying it as an entire identity from the risk management perspective. There are available models to improve risk management practices in general, but there is a lack of having a specific model that endorses risk management practices in recovery projects.

2.4 Critical Success Factors in Risk Management

Risk management is an essential part of the construction and infrastructure industry, and its effectiveness is often vital to increase project success (ISO 31000, 2009). Failure to improve risk management processes can contribute to the failure of achieving organisational goals and objectives and reduce stakeholder's confidence and trust. Thus, it is essential to investigate the Critical Success Factors (CSFs) of effective risk management best practices (Manaba et al., 2012). CSFs have been an active part of research in the last decade, but there is a gap in investigating CSFs for recovery systems. Some of these studies are as follows;

Grabowski and Roberts (1999) and Galorath (2006) have confirmed that CSFs are associated with risk sensitivity culture, leadership, structure, roles, responsibilities, information technology infrastructure, measurement methodology and collaborative environment.

Ranong & Phuennga (2009) identified seven critical success factors that could endorse the effectiveness of risk management procedures and performance. The factors are organisational structure, commitment and support from top management, trust, organisational culture, information systems and technology, effective communication, and training.

Hosseini et al. (2016) found that support from managers, awareness of the process for implementing risk management and training courses for construction practitioners are crucial factors for effective risk management in the construction industry. Cagliano, Grimaldi and Rafele (2015) and Ram and Corkindale (2014) illustrated the importance of promoting teamwork, effective communication, training and collaboration and culture environment among the parties involved are critical to step up the risk management performance.

Chapter 7 in this study was dedicated to investigating the CSFs inside post-disaster recovery systems.

2.5 Risk Management Maturity Inside SCIRT

Botha & Scheepbouwer (2014) explored the risk management inside SCIRT through two phases the Ramp-up phase and the Steady State phase. The Ramp-up phase represented the early period where the risk management procedures and practices faced serious challenges. There was a challenge to design this large volume of work after the disaster with significant lack of resources and meet the delivery deadline. That caused infrequent early contractor involvement in project design. This meant that fewer risk and constructability workshops were held affecting the projects' performance.

As the processes and systems of SCIRT developed and matured, ECI became a more formalised process. Projects designed in this period had risk and constructability workshops that were attended by the ECI team in order to mitigate the construction risks in design where possible. Consequentially, the RMM inside SCIRT had increased. This period called the Steady State phase (Botha & Scheepbouwer, 2014).

The difference between these two periods in SCIRT was used to investigate if there is a correlation between specific performance measures and risk management in post-disaster recovery systems in Chapter 7.

2.6 Analysis Methods.

The analysis methods used in this research were selected after the research questions were defined through initial research investigation with construction and risk professionals in the SCIRT programme using interviews and brainstorming sessions. This initial investigation has emphasised the complexity of recovery systems related to risk management and highlighted the need to study the post-disaster recovery systems, as a whole, using proper system analysis methods. Accordingly, ST & SD were chosen to understand the complexity of the recovery systems in conjunction with different analysis methods to answer the research questions. By using ST, opportunities and problems in specific areas such as the critical risk types, the concurrent work through the programme lifecycle, the interaction between the different layers of risk management, and the factors that drive the risk management in recovery projects were highlighted for further investigations and shaped the research questions.

The following section gives an overview of the analysis methods that were used to answer the research questions. More information about the initial investigations and the research methodology are available in Chapter 3 and 4.

2.6.1 System Thinking and System Dynamics

ST and SD are well-known in the research arena as an integrated way of analysing systems and organisations, and both have been used widely to understand systems better. Some of the previous research that successfully used ST and SD are:

O'Donnell (2005) applied ST to develop a framework in ERM level for the organisations to face events that could affect its abilities to meet its strategic or operating goals. The author promoted ST in the risk assessment and the procedure to identify risk events which could impact the business process performance. Also, used it to develop a map of the organisation value chain and present the different component of the business model.

Pezza & Pinto (2018) applied ST to develop a simple approach to make decisions inside coastal infrastructure systems. The authors offered a framework for a more integrated system approach to aid the coastal community from future flooding risks.

Agarwal & Virine (2019) used ST to understand the differences between PRM and ERM processes and the integrations between both levels. The authors highlighted the importance of finding an integrated approach to relate the isolation processes in different projects inside the project-based organisations. The authors provided formal and informal approaches of the integration between both levels and the requirements for such integration such as the improvement of the risk culture, the risk expertise, and the team building.

Rodrigues (2001) mentioned that project risk dynamics are difficult to understand and control, which required further developments in the risk management field to manage these dynamics. The author presented SD as a solution to understand the dynamics of risks inside projects in conjunction with the PMBOK risk management process. Also, the author highlighted the advantage of using SD in presenting the problems and its benefits of offering effective management solutions.

Wang et al. (2005) discussed the advantages of SD in managing project risks dynamics in complex systems. The authors highlighted the importance of using SD as an integrated way to understand the dynamics of risks inside complex projects.

Nasirzadeh et al. (2008) applied SD as an integrated way to investigate risk management in construction. The authors explained that due to the interactions between internal and external factors throughout the project lifecycle, the complexity of risks increased inside construction projects. The authors promoted SD to understand risk management and used it to develop a simple approach to support different stages of the risk management process in construction projects.

The above studies represented similar studies to our study that used ST and SD in the field of risk management. As above, it is obvious the benefits of using ST and SD to analyse complex systems as it represents an integrated way of investigating risk management in post-disaster recovery systems as a whole and exploring the risk dynamics inside these systems.

In this study, ST is represented by System Theory Methods (STMs) and System Dynamics (SD) is represented by the modelling tool; the Causal Loops Diagrams (CLD).

2.6.1.1 Causal Loops Diagrams in Risk Management

CLD is an SD tool to model and simulate the behaviour of a dynamic system, allowing visualisation of the important parts of a system and showing how they interrelate, it starts with the areas that already known and then follows the influence of this part until it reaches the system boundary (Kirkwood, 2013).

Sterman (2000) used SD to express the behaviour of the system using animated mathematical simulation, which was a powerful tool for generating immediate predictions from theory and observing the variance in general behaviours. Ssemaluulu & Williams (2006) used CLD in the risk management field in the information systems industry. They used it to present risks that influence the challenges in developing information systems. CLD showed that risks in information systems are caused by uncertainty, and complexity leading to cost overruns and low user satisfaction, which continue to be a challenge to information-systems' managers and professionals. Therefore, CLD was used to create a better understanding of improving information systems before they are implemented.

Allan et al. (2008) used SD modelling to understand the performance of the NZ construction industry. The modelling provided a better understanding of the dynamics and the interactions surrounding the construction industry in NZ, which are critical to the key finding of this research. The study showed that the complexity and the uncertainty of the NZ construction industry demand changes in the industry structure and strategic thinking to encourage collaborative learning processes. In the same manner, CLD was used to stimulate and model the collected data in this study and present the main outcome and question.

2.6.2 System Theory Methods in Risk Management

Systems theory introduced in the 1940s by Von Bertalanffy and developed further by Klir in the early '90s (Klir, 1991; Bertalanffy, 1969). Klir (1991) described systems theory as the theoretical study of a system to investigate the common themes. That could involve using more than one academic discipline or tool to create something new by thinking across the boundaries and break the complexity of these systems (Newell, 2001).

One of these complex systems is the construction industry, construction multi-projects have been operated in a complex management environment; for decades, this has been recognised as a key challenge in the construction industry (Frame, 2002). Risk management is a part of this complex system. From there, the idea was developed to use STMs to study and investigate SCIRT in this research.

Aritua et al. (2009) defined complex systems with six components, which are inter-relationships, adaptability, self-organisation, emergence, feedback and non-linearity. They suggested using new analysis and decision-making tools to break up this non-linear complexity. Nicolis & Prigogine (1989) illustrated that with the exposed complex systems, it is important to use system theory to break the insights of such interactive and dynamic systems.

The use of systems theory and systems analysis methods is still not widely implemented in risk management. Skoko (2013) applied it to risk management in environmental and human health areas, and he introduced STMs to evaluate the complex and dynamic interactions among multiple factors such as organisational, system, and external environmental factors.

STMs developed paradigms, which are based on sets of concepts and ideas, to better understand and deal with complex situations (Skoko, 2013). STMs contain five stages, identify problems and opportunities, reflect and analyse interactions, understand possibilities and the dynamics, develop solutions sustainable decisions, and finally consolidate and realise processes (Buerki, 2006).

Skoko (2013) recommended the concept of using STMs to investigate risk management in recovery systems for future studies. Therefore, STMs were used to answer the third question in this research "what are the interactions between risks in the three levels (SRM, ERM, and PRM)?" through two steps; creating the impact matrix, which shows the intensities in the factors interactions and developing the map of interactions, which shows a picture of the dynamics inside SCIRT.

2.6.3 The Use of Analytical Hierarchical Process in Risk Management

AHP is one of the Multiple-Criteria Decision Making (MCDM) methods. It is a decision-making technique to utilise the quantitative and qualitative data pair-wise comparisons and develop the measurements based on a ratio scale (Saaty, 2006). The multi-criteria complex decision problem is broken down into the various criteria and sub-criteria for weighing the solutions of the different alternatives through the process. The main contribution and characteristic of it are the quantifying of the qualitative factors and alternatives (Saaty, 2006; Saaty & Shang, 2011).

AHP helps seize objective and subjective analysing procedures, providing a mechanism that is valuable for inspection of calculations' consistency in order to minimise the preferences and discrimination in making the decisions. While making difficult decisions relating to a wide variety of standards, the primary step is to disaggregate the key areas into basic goals, objectives and substitutes (Ishizaka and Lusti, 2003).

AHP is a flexible process used for achieving structural decision-making and considered judgment of different experts, generating results, which sustain a useful base for decision-making (Escobar et al., 2004). Mustafa and Al-Bahar (1991) introduced AHP as a new method for project risk-management assessment. They used AHP to assess the risks of constructing a bridge project and identify the overall level of risks and evaluate the alternatives responses to risks based on expert judgments.

According to Vaidya and Kumar (2006), AHP supports the decision making of selecting the most appropriate alternative from options and evaluating the alternative options. In choosing one alternative from different options, it is not necessary for risk management to decide by choosing one variable only. However, considering the possibilities is a good option to make a suitable decision. On the other hand, in order to prioritise the alternatives, according to Cox et al. (2008), many problems in the process of risk management need the decision makers of the organisation to make prioritised decisions. It depends on the benefits analysis outcomes, but in most cases, the decision is more driven by financial gains. In other words, the options with better cost-benefit analysis outcomes are commonly the favourite for organisations.

Li et al. (2013) used AHP in risk identification for an open-cut subway construction project. Sharma & Pratap (2013) illustrated the use of AHP to rank risk factors in risk identification and determine risk optimisation in the manufacturing supply chain. He found that the industrial risk and then product risk are the highest impact on the successful implementation of a supply chain and suggested to develop a formal decision framework to identify solutions.

Rao et al. (2014) build a systematic framework of schedule risk management for Power Grid Engineering Projects (PGEP) using AHP. His paper established a three-dimensional risk management system that contains management personnel, periods and methods. It used a three-tier evaluation system, which included five indexes; risk probability, risk uncontrollability, risk category, duration extension size and risk accountability. The new framework aimed to improve and ease the difficulties in risk management for PGEP.

AHP has been in use in risk management outside the construction industry. Sum (2015) explained that AHP, as a decision-making method, is widely used in supply chain risk management and project risk management but has not been explored yet in risk management of an enterprise. Moreover, he highlighted the lack of formal analysis of decision making in risk management and the potential of using AHP to fill this gap.

Toledo et al. (2013) used AHP to evaluate the risk factors in the agriculture sector. The authors tried to deliver an estimate of weightings that measured the significance of different risk factors on farmers while ranking of a set of productive substitutes. A multi-criteria optimisation procedure was developed to include factors that interrupt the decisions involved in creating an agricultural activity. The main objective was to establish a grading hierarchy system of agricultural activities in terms of risk level.

All the previous researches give clear evidence that AHP is a reliable method in formulating the decision-making based on the hierarchical process to handle complex decision formulation. It could be used to improve the risk manager's decision-making in risk management and simplify complex problems for more structural decision-making (Sum, 2015). From this, the idea was developed to use

AHP to answer the first question in this study "What are the critical risks in the three risk management levels (SRM, ERM, and PRM)?".

2.6.4 The Use of Qualitative Comparative Analysis in Risk Management

QCA is a systematic, holistic analysis of a moderate number of cases based on comparing the configuration of selected variables across these cases as a way to generate the same outcome (Krivokapić-Skoko, 2003).

There are robust methodical tools that could be used in QCA, including impact matrix, and truth table using Boolean analysis (Skoko, 2013). The application of QCA starts from choosing causal variables followed by the operationalisation of the outcomes using the existing theoretical views and realistic literature. A coding procedure for the variables using presence /absence dichotomy was done to operate Boolean algebra analysis. Analysing data starts with building a raw data matrix to create a truth table of the variable and the outcomes using binary mathematical forms. Then the matrix is subject to Boolean minimisation. (Skoko, 2013)

Cioaca (2011) presented the use of QCA in risk management in aviation projects. The author used a multi-criteria analysis to achieve a comparative evaluation. The chosen criteria were consistency, applicability, design, dynamic, and utility. Then, the share of each criterion was established on a grid of three values in order of importance (0, 0.5 and 1). After comprehensively analysing this, Cioaca (2011) explained that the consequences of several external and internal events required a comprehensive risk evaluation with quantitative and qualitative analysis capabilities.

Similarly, QCA used in this study to find the success factors in effective risk management, which was directed towards answering the second question "What are the Critical Success Factors (CSFs) for effective PDRM in the construction industry?"

2.7 Summary

After a scan of the existing literature on risk management after an event, the studies have been categorised into TRM and DRM. TRM was then sub-categorised into SRM, ERM, and PRM. This is highlighted the lack of exploring the difference between risk management practices before and after a disaster and investigating post-disaster recovery systems in particular. Previous studies recommended investigating the risk management strategies, framework and process under various situations and circumstances, which was the primary motivation of this study. This study covers this gap by investigating SCIRT as a case study for a recovery system to develop an integrated PDRM model that can be used in post-disaster recovery systems for more effective risk management.

Overall view of the selected analysis methods has been covered in this chapter. The investigation of the recovery systems as a whole was found to be recommended using ST and SD in conjunction with different decision-making methods. A comprehensive validation of the study and the research methodology are covered in chapter 3 and Chapter 4. The below table summarised the research objectives and the methods used to achieve these objectives.

Table 2.1: Summary of the research objectives and the main methods used.

Research objectives	**The main methods used**
What are the critical risks in the three risk management levels (SRM, ERM, and PRM) inside post-disaster recovery systems?	Analytical Hierarchical Process (AHP)
What are the interactions and the dynamics between risks in the three levels (SRM, ERM, and PRM)?	Qualitative Comparative Analysis (QCA)
What are the CSFs for effective PDRM?	Systems Theory Methods (STMs)
Developing the PDRM model	Causal Loops Diagrams (CLD)

Chapter 3: Research Methods

3.1 Introduction

In this chapter, the conceptual framework and the research methods used in this case study research were covered, including research validation, the data collection and the data analysis stages. Both qualitative and quantitative data has been collected using interviews; brainstorm sessions and a survey. ST and SD approaches in conjunction with different analysis methods represented the core of the methodology in this research.

3.2 Conceptual Framework

After an examination of the existing literature on risk management, this study presents a leading position of using system theories and system dynamics, in conjunction with analytical decision-making methods, to investigate the recovery systems after a disaster.

Figure 3.1 shows how the conceptual framework initially established to investigate the research case study “SCIRT”, represented in the far-left column, to develop the research outcome, which is the PDRM model, represented in the far-right column. The research methods is divided into four main stages, the research validation stage, the data collection stage, the data analysis stage and the model development stage.

The research validation stage was directed to identify the differences between TRM and PDRM and develop the research questions using ST to interpret the existing data in the case study against ISO 31000 process. This was achieved through initial interviews and brainstorming sessions.

In the main data collection stage, both qualitative and quantitative approaches represented by semi-structured interviews, survey and project history records of the case study have been used.

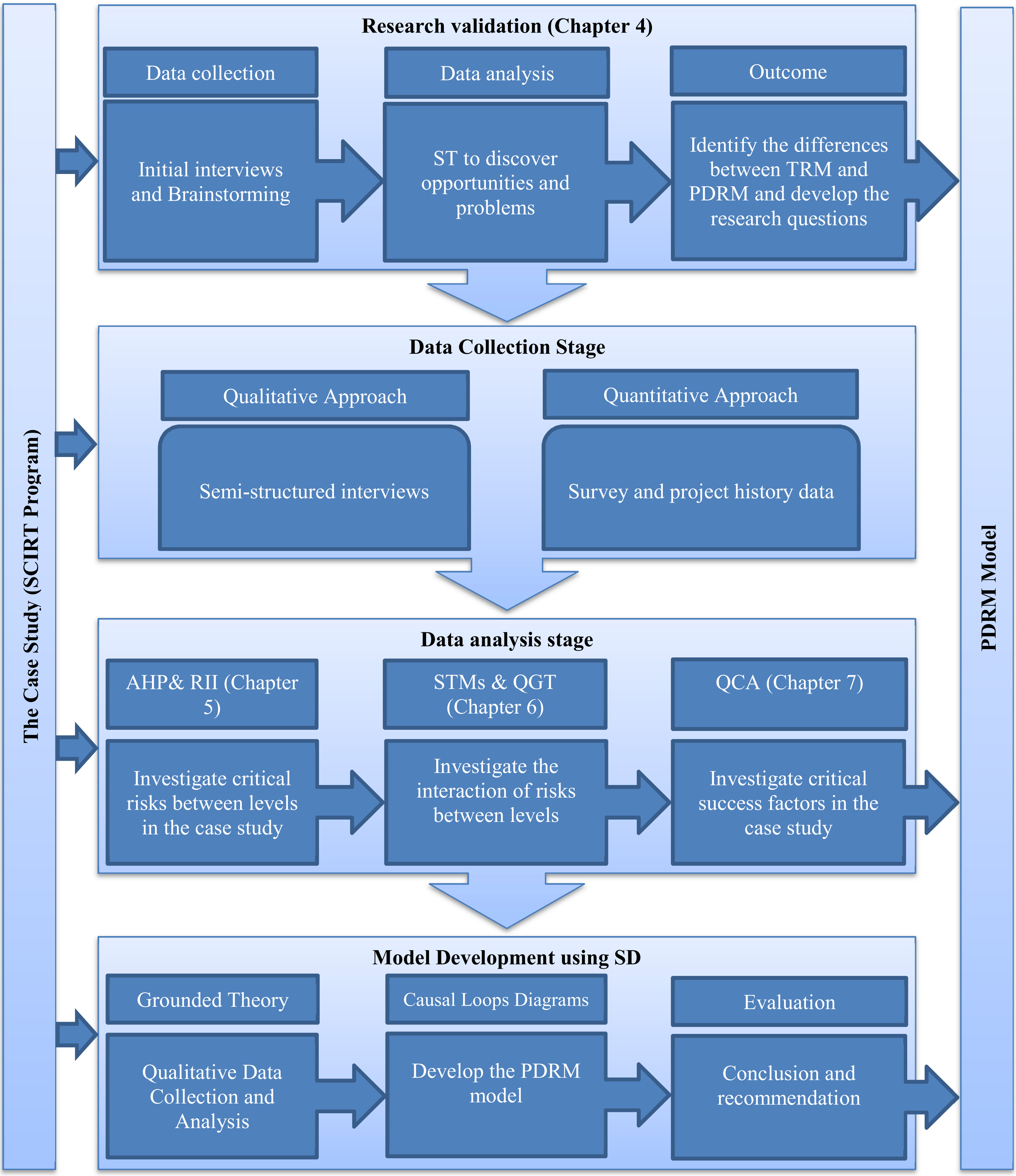


Figure 3.1: Flowchart of the research methods.

The overarching methodology of this study is based on ST and SD. However, due to the complex character of recovery systems, several analysis methods have been used in the data analysis stage, allowing a more integrated approach and endorsing more reliable outcomes.

The study aims and objectives were achieved through the application of quantitative and qualitative approaches to data collection. In addition, the implementation of different system theories and analytical decision-making methods in the data analysis and the outcomes have been developed using CLD.

3.3 The Case Study Approach

The importance of analysing the historical information of the companies or individuals and investigate their experience to assess the best practices of risk management in projects is undeniable. Therefore, the case study approach seemed to be the most suitable for this study. Yin (2009) stated that the case study as a research approach is a great tool to explain the presumed causal links in complex systems. It could be a single case or multiple. Denscombe (2003) mentioned different benefits of using case study approach as it gives the ability to use a variety of sources of data and easy to mix it with different research approaches. Also, identifying the criteria for selection of candidates, exploring the appropriate literature review, and declaring the gaps to investigate were the foundations of case study selection and development.

Czerwinski (2009) stated that recovery from major disasters is a complex undertaking that contains the combined efforts of all levels of government in order to succeed, and SCIRT was not an exception. SCIRT was a recovery system that exhibits many attributes of a complex alliance model with multiple owners and non-owners, and an extensive programme of work with massive damage scale makes it more complicated than usual. SCIRT was operating in an uncertain environment. It meant to have a clear sense of purpose, which is the infrastructure recovery of Christchurch. The complexity generated from the need to cooperate with other recovery works, such as residential recovery, which were happening at the same time (Office of the Auditor-General, 2013). Although SCIRT concerns one alliance, the number of separate projects (over than 700) makes it unique and gives it a complex character.

3.4 Data Collection

3.4.1 Participant Attributes

The data has been collected from risk and construction professionals and top management from the SCIRT alliance covering the three levels of management from the client(s), from the SCIRT and the delivery teams. Participants included were from client representatives, SCIRT head office staff, and delivery team's project management crews.

Altogether 101 risk and construction professionals participated in this research (6 in initial interviews, 15 in the brainstorming workshops, 60 in the main survey (survey questions are available in Appendix B), and 20 in the main interviews (interview questions are available in Appendix C). The interview participant's number represents almost 90 % of the total population of SCIRT board and 55% of the top management, while the survey participants represent 20% of the programme team. The coverage of both the survey and the interviews was aiming to represent an acceptable picture of SCIRT practice. The participants were chosen based on their involvement in risk management inside the SCIRT programme. The participant's titles included are client representatives, designers, project managers, estimators, quality controls, project engineers, and even the decision makers from the top management. The participants were selected from the three management levels (client, SCIRT and Delivery teams) to ensure the diversity of the data and for more comprehensive coverage of SCIRT programme. Table 3.1 represents the type of participants involved in this study.

Table 3.1: Participants' characteristics.

Demographic	Initial Interviews (n=6)	Brainstorming (n=15)	Main interviews (n=20)	Survey (n=60)
Management level				
Client			20%	10%
SCIRT	50%		40%	15%
Delivery Teams	50%	100%	40%	75%
Position				
Top management	100%		50%	23.3%
Project Managers		100%	20%	30%
Estimators			10%	5%
Designers				6.7%
Project controls			20%	10%
Project Team				25%
Age				
<25				8.3%
26-34		20%	15%	33.3%
35-54	83.3%	80%	75%	45%
55-64	16.7%		10%	11.7%
>65				1.7%

**The figures represent the percentage of the categories inside each data collection method.*

As in Table 3.1, the participants came from all three levels of management. The delivery teams represent the majority, as they represent a larger group than the client and the management teams. Therefore, due to the low number of the staff in client and management teams, delivery team participants have been asked to share their views as if they were representing the client or SCIRT in some questions. Moreover, the participants have an individual experience based on their positions and their ages range, and they had direct involvement in risk management inside the SCIRT programme. The majority of the participants contributed at some stage in the projects risk management workshops.

3.4.2 Data Sources

According to Lunsford (2005), data can be collected using primary and secondary sources. Primary sources are tools used by researchers such as survey and interviews with participants who are part of the study. Secondary sources of data include literature, guides and standards. The primary data used in this research was mainly constructed from participants with direct or indirect relevant experiences and was collected by interviews and survey combined with statistics data from SCIRT programme. While the secondary source was more into exploring the related studies in the research market.

The data source of the research validation “Chapter 4” came from the initial interview and the brainstorming session, while for the other chapters share the same source of information which is the main interview and the survey. The survey was divided into sections that cover specific inputs for each used analysis method in this research.

The collected data was a mix of narrative information from the professionals’ experience in risk management, financial and schedule information from projects inside SCIRT to measure the project’s success and the risk management information.

3.4.3 *Qualitative and Quantitative Research Approaches*

In this study, a mixed approach has been used to combine the benefits of both and for better-integrated outcomes. Qualitative and quantitative research approaches, each has its advantages and disadvantages. Kwortnik (2003) found that quantitative approaches were more deductive, objective, conclusive, independent, and better suited for statistical analysis. Qualitative approaches were more inductive, subjective, impressionistic, holistic, and aimed to understand the case studies. In this research, a mix of qualitative and quantitative data collection approaches is utilised in order to combine the benefits of both. According to Lichtman (2006), the qualitative approach is more suitable to understand and interpret social interactions. It can suffice with smaller and not randomly selected groups, to study the whole instead of the variables. Data can consist of the collection of frequently used words, images or objects from open-ended responses. This qualitative approach is based on the exploratory or bottom-up scientific method, which is more dynamic and situational, where the researcher generates a new hypothesis or theory from the collected data. Nevertheless, qualitative data is an important source of data for SD modelling (Luna-Reyes & Andersen, 2003). It is a great base to identify problems, early conceptual modelling and overall modelling process (Forrester, 1992). On the other side, a quantitative approach is more into testing hypotheses by looking at the cause and effect and make predictions from large and randomly selected groups with specific variables to study. Moreover, the collected data normally constitutes of numbers and statistics, which are based on precise measures using structured collected data (Johnson & Christensen, 2008). Qualitative approaches have been used more than quantitative approaches in management and organisational sciences (Sandberg, 2005). Lindlof and Taylor (2002) defined a semi-structured interview as a method of research used in social sciences, which allows new questions to be asked during the interview. The authors advised researchers to group and prepare questions, which could be used in different ways for different participants. That allows the researcher to direct the interview towards achieving the desired main objectives.

In this study, the data collection was divided into two stages, the data collection for the research validation, and the data collection for the main research investigation. In the research validation stage, initial interviews and brainstorming sessions were used as data collection tools to discover the opportunities and the problems of the entire recovery system "SCIRT" and develop the research questions.

In the main research investigation stage, semi-structured interviews, surveys and project data was used as qualitative and quantitative data to answer the research questions. Information technology was used in this research to facilitate the data collection, such as using the online survey tool "Qualtrics Online Survey".

3.4.4 Pilot Study

Before going forward into the field of data collection; a pilot study as a preparatory activity was used in order to improve the survey accuracy. Lancaster et al. (2004) defined a pilot study as a small experiment designed to test the logistics and the quality of the collected information. In present research, a pilot survey was conducted with applicants out of the overall population used in this study to check the quality of the collected information and to be ready for filling the gaps in the final survey and interview questions. After collecting the data, it was analysed. The analysis process started with proofing and filtering quality data by measuring its importance about answering the research questions, and finally analysing the data and focusing it towards conducting the new findings (Ader & Mellenbergh, 2008).

Overall, the major benefits of conducting these pilot interview and survey in this study were to reduce and restructure the interview questions, identify any new aspects to focus on, and improve the interview skills.

3.5 Data Analysis

Several analysis methods used in this research to break down the complexity of the recovery system. The data analysis methods used are as following;

1. AHP and RII were used to investigate critical risks between levels, as both are effective decision-making methods in a systematic approach (Renuka, Umarani and Kamal, 2014; Holt, 2014).
2. STMs and Quantitative Graph Theory (QGT) were used to investigate the interaction of risks between risk management levels as both are effective in studying systems to investigate the common principles and the quantification of structural data to graphs (Dehmer et al., 2017; Klir, 1991).
3. QCA was used to investigate the success factors because it is a practical analysis method to capture the complex causations in a complex system such as a recovery system (Rihoux & Ragin, 2008).
4. SD modelling based on GTA was used to develop the PDRM model as both are effective to represent the influence of variables in complex systems (Strauss & Corbin, 1998; Eker & Zimmermann, 2016).

The reasons for using these methods include the following;

- The recovery systems are considered to be complex. The use of multiple analysis methods and tools while studying complex systems is recommended by several researchers such as Kilr (1991) and Aritua et al. (2009) to break the complexity and to give more extensive exposure for better outcomes.
- The choice of methods was based on the effectiveness of these methods to analyse complex systems and the ability to answer the research questions and achieve the outcome of the research.
- These methods have been recommended for further research and promoted to be used in risk management by researchers in previous studies. Examples of AHP studies are (Sharma & Pratap, 2013; Toledo et al., 2011; Sum, 2015). Examples of QCA studies are (Cioaca, 2011; Moritz et al., 2011; Huntjens et al., 2011). Examples of STMs are (Skoko, 2013; Buerki, 2006). Examples of QGT are (Fahimnia et al., 2015; Dehmer et al., 2017). Examples of SD are (Dragulanescu & Androniceanu, 2017; Punyamurthula & Badurdeen, 2018; Wu et al., 2010).

- The diversity of the used methods helped in providing an integrated way of analysing the system, including procedures, performance, and surrounding risk management environment.
- Even though each analysis method was principally directed towards answering specific questions in this research, there was a benefit of comparing the outcomes of each method.
- The variety maximises the achieved outcomes and minimised the influence of unpremeditated consequences.
- This methodology is effective because it started with a narrative report from real case study experiences with contextual descriptions from the research participants supported by statistical data to provide richer findings (Lichtman, 2012).

The following section describes the main analysis methods (AHP, QCA, STMs and CLD) briefly, and how it was used to develop the research outcomes. The remaining methods were covered under their specific chapters to assist the research flow and give a better understanding of the chapter and the methods.

3.5.1 Analytical Hierarchical Process

The need to investigate the critical risks in recovery projects has been raised after the research validation stage "Chapter 4". AHP is applied in this study as it is a useful method for more effective decision making in a systematic hierarchical way (Renuka, Umarani and Kamal, 2014). The literature review covered the application of AHP in risk management and explained how useful AHP is for the decision-making in risk management.

The motivation of using AHP is to gain better insight into complex decision problems. With this method, the most important criteria relating to decision making can be identified, and the use of pairwise comparisons and logical inconsistencies can be uncovered. AHP allowed translating individual opinions and feelings into measurable numeric relations. It supports decision making more understandably and proactively (Escobar et al., 2004). This method was used to determine the critical risks inside each management level. The AHP was used to delineate a decision structure with the possible post-disaster risk factors between the different management levels.

Three main elements need to be clarified before starting AHP analysis, the objectives, the main criteria, and the sub-criteria. The objective is to identify the critical risks in the system; the main criteria are the management levels and the sub-criteria are the risk factors inside these levels. Figure 3.2 shows the risk assessment model that has been used in this research.

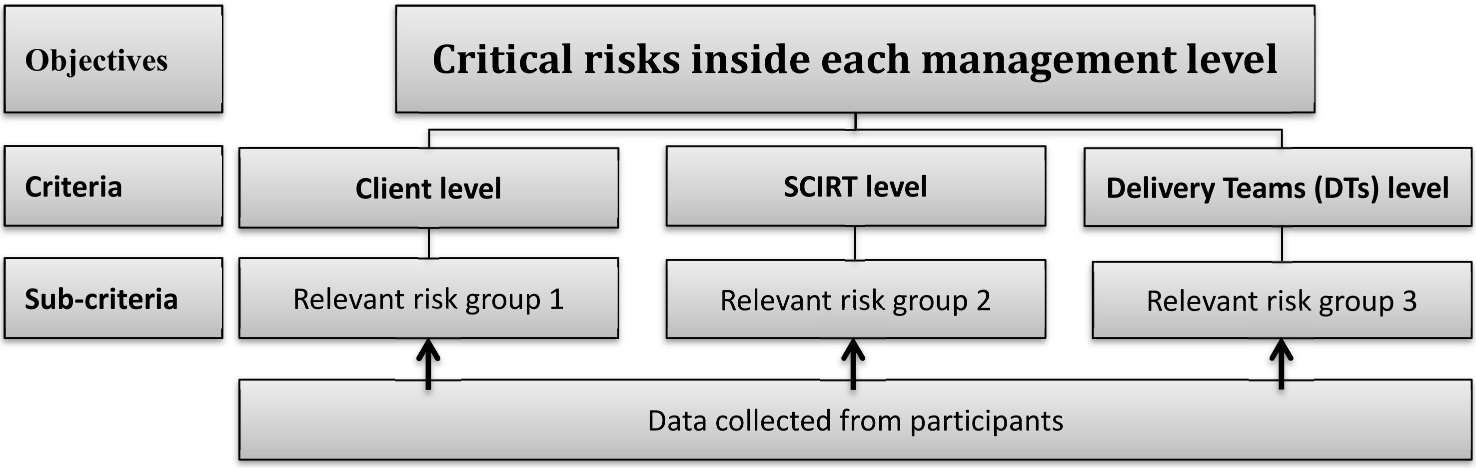


Figure 3.2: AHP risk assessment in this research.

The following steps have been used:

- Identify objectives, which are the critical risks
- Identify each risk management level (SRM, ERM, and PRM) from the survey and the interviews (criteria identification)
- Identify the significant risks inside each level using survey and interviews (sub criteria identification)
- Rank all the risks inside each level and compare them with the other management levels (1 represents equally critical, and 5 is extremely critical) from the survey. (Figure 3.3)
- Arrange the results in a matrix
- Compute the normalised principles Eigenvector of the matrix.
- Evaluate the combinations by checking the highest ranking
- Identify the critical risks

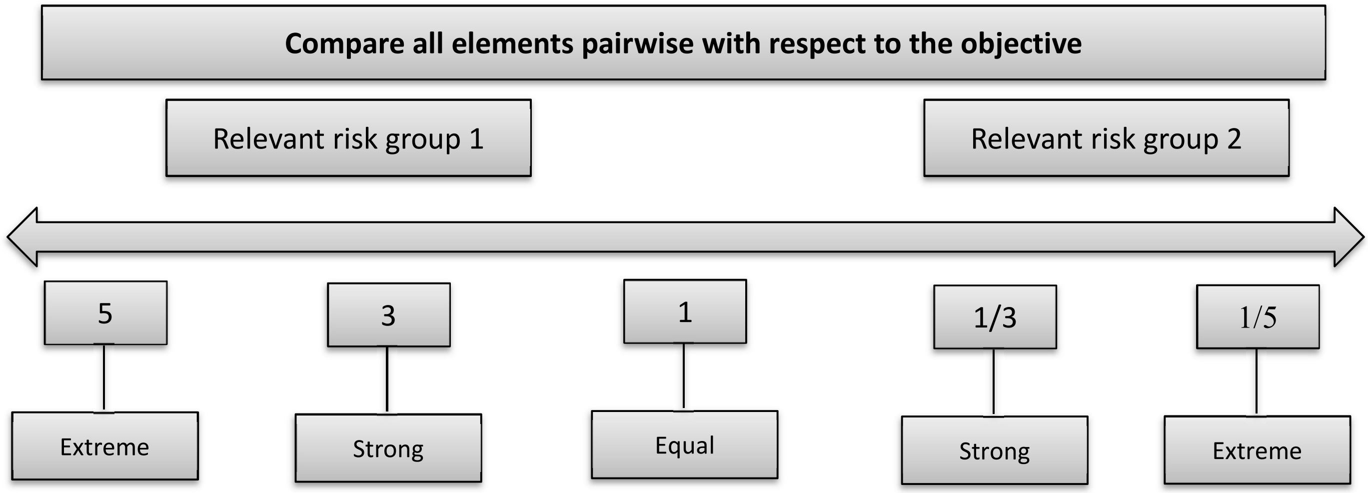


Figure 3.3: Compare the risk pairs using AHP.

The inputs for AHP were data collected with a survey. The survey was conducted to identify the critical activities and the relevant critical risks inside each management level. Participants weighted each risk according to its importance and its relationship to each other based on their work experience (5 is extreme (+) & 1/5 extreme (-)). A comparison between the sub-criteria and criteria was made in pairs to identify the critical risks (Figure 3.4). For example, participants compared the funding risks in client-level against safety risks in the delivery team by marking the place along the segment to represent the most important risk group from their perspective between the pairs.

3.5.2 Qualitative Comparative Analysis

In construction project management, the end goal is to achieve a successful project and, the raw definition of a successful project is to deliver the desired scope within the planned budget, planned schedule and the expected quality (PMI, 2013). In this study, investigating the Critical Success Factors (CSFs) inside recovery projects have been raised as a question after the research validation stage "Chapter 4". The methods to investigate the CSFs has been done in two dimensions, directly through survey and analytically through using QCA by examining the data of a hundred recovery projects from SCIRT programme.

QCA is a comparative analysis, which has an explicit goal to explain the seams in the system (Rihoux & Ragin, 2008). QCA used to determine the Critical Success Factors (CSFs) for more effective risk management in recovery projects. QCA allows us to look at how a combination of factors work together to achieve success. In particular, the relationship between the different project management factors inside the system such as cost, schedule, environmental, safety and quality performance indicators, and the RMM. it This should give a better understanding of the main drivers of effective risk management in recovery projects.

According to Ragin (2000), the QCA analysis includes the following phases, identify relevant cases and causal conditions, establish crisp data matrix (Crisp-set analysis), construct the truth table and resolve contradictions, analyse the truth table, and finally evaluate the results and the findings.

Figure 3.4 shows the steps for QCA in this study. As QCA focuses on the cases as a whole, SCIRT is an excellent case study for recovery projects. It has hundreds of infrastructure projects with various asset types. Each project has its uniqueness, own risks, and own way of management; however, all projects have the same end goal, which is to achieve a successful project. A hundred projects from SCIRT programme have been chosen randomly to investigate the relation between the different factors “performance indicators” and RMM in post-disaster.

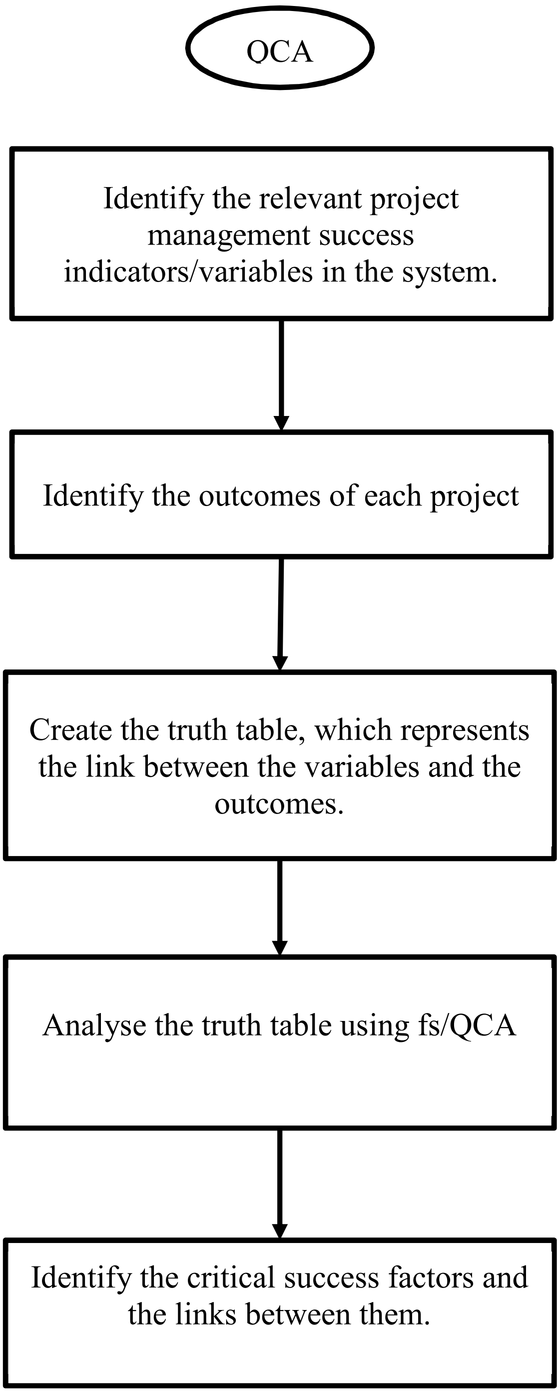


Figure 3.4: QCA in this research.

The selection was made ensuring the reasonable coverage among varies projects and the five main contractors.

Inside SCIRT, infrastructure assets divided into the following

1. Waste Water projects (WW)
2. Waste Water Pump Stations projects (WWPS)

3. Storm Water projects (SW)
4. Storm Water Pump Stations project (SWPS)
5. Water Supply projects (WS)
6. Water Supply Pump Stations (WSPS)
7. Roading projects (R)
8. Structural projects: bridges and retaining walls, etc. (S)

These cases (projects) were examined against the existence of independent and dependent factors represented by (1), if present, and (0), if absent. The factors were determined based on the available information inside the SCIRT system.

The factors were cost performance index, schedule performance index; number of work scope changes, number of incident reports, and number of non-conformity reports. The outcome was determined as RMM. Table 3.2 shows a sample of the truth table that has been used in the study.

Table 3.2: Representative Truth Table.

Cases		**Factors**					**Outcomes**
Projects	**Project type**	**Cost performance index**	**Schedule performance index**	**Number of work scope changes**	**Number of incident reports**	**Number of non-conformity reports**	**RMM**
1	WW	0	0	0	0	0	0
2	WWPS	1	0	0	0	0	1
3	WS	0	0	0	0	0	1
4	WSPS	0	0	0	0	0	0
5	SW	0	0	0	1	1	0
6	SWPS	0	0	0	0	0	0
7	R	0	0	0	0	1	0
8	S	0	0	0	0	0	1
9	WW	0	0	0	1	0	0
10	WWPS	0	0	0	0	0	0
…	….						

After the truth table had been finalised, a Boolean technique was used to create a combination logic from the original configuration. Then it was minimised into stages by software to show the conjunction of primitive equations towards the final equation. There are some software packages in the market to facilitate this, such as GUI Software includes fs/QCA (Version 2.5), Kirq (Version 2.1.12), and Tosmana (Version 1.3.2.0); in this study, fs/QCA (Version 2.5) has been used.

3.5.3. Systems Theory Methods

The STMs are based on two tools, the impact matrix and the interaction map. The impact matrix was used to rank the related risks inside each level based on its influence on each other and on the system. The interaction map was used to identify the interactions between these risks.

Skoko (2013) explained the steps included in STMs as following; identify problems and opportunities; group the risks under appropriate drivers using holistic and potential structure tests; reflect the interrelations using the matrix, and visualise the dynamics using the map of interaction to understand it (see Figure 3.5).

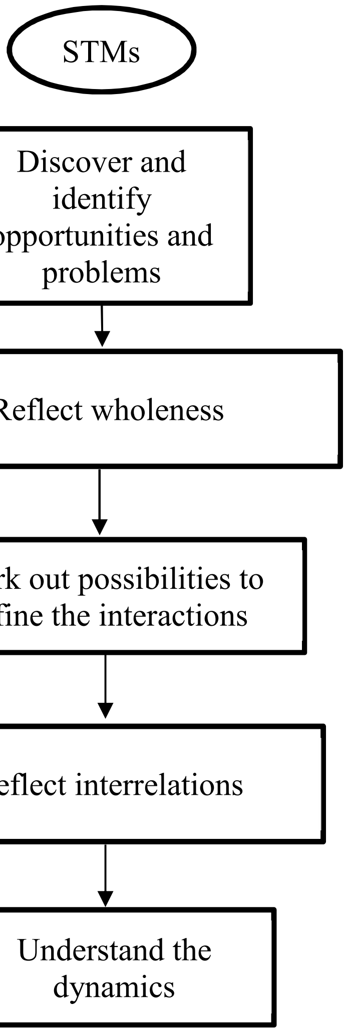


Figure 3.5: STMs in this research based on Skoko (2013).

In this research, the risks in each management level have been identified and grouped, then the influence of these risks into each other's and the system has been represented into impact matrix based on participant inputs (0 for weak influence and 4 for strong influence), then the interactions have been represented using the Graph theory.

The outcome of this method was the development of the research questions as a first step and later on to identify the interaction between the critical risks throughout the three levels and analysis of the influence of these interactions on the entire system. That has been done by ranking the risks according to scoring strategy, creating the influence on the impact matrix to identify the upstream and downstream influence of each risk to the entire system; and finally drawing out the interaction map between risks.

3.5.4. System Dynamics Modelling and Grounded Theory Approach

Grounded Theory Approach (GTA) is considered a powerful research approach for collecting and analysing qualitative data and provide a basis for the development of the SD modelling-based coding process (Eker & Zimmermann, 2006). Strauss and Corbin (1967) presented GTA in the 1960s to investigate the actualities in the real world and analyse the data with flexibility. It was described by Allan (2003) as a data analysis stage to search out the concepts behind the facts by looking for codes, then concepts, and lastly categories. GTA relies on dividing data into parts for comparison and grouping these parts into categories (called open coding) and connecting categories and subcategories hierarchically (called axial coding) (Strauss & Corbin, 1998).

Also, SD modelling is powerful in representing the interaction of variables in complex systems. One of the methods to gather qualitative data in SD is conducting interviews. These interviews can have the form of structured interviews, formal and organised with prearranged questions (Hall et al., 1994) that could include direct questions about the causal relationships that connect the variables in the system. Alternatively, they can take the form of semi-structured interviews which pose more open questions, and which allows the interviewee to share their experience about the point of research (Eker & Zimmermann, 2006).

In the modern research market, researchers have used different software to automate the coding process and reduce the time consumed. A summary of the formal coding procedure and the creation of CLD used by Kim and Andersen (2012) is shown in Figure 3.6.

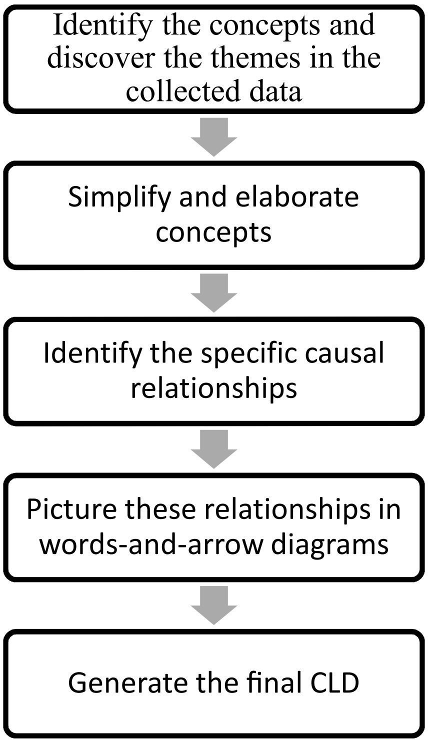


Figure 3.6: Summary of coding process to create Casual Loop Diagrams according to Kim and Andersen (2012).

A similar procedure has been used in several studies. Yearworth and White (2013) introduced the use of software called CAQDAS (Computer Assisted Qualitative Data Analysis) to maintain the links between the coded information and generate the CLD. Eker and Zimmermann (2016) used a housing sector case study from the UK to investigate integrated decision-making. They developed an alternative approach to generate the CLD after analysing the data using NVivo 11 software. This approach focused on causal relationships from the start of the coding process using NVivo, and they cut the time consumed by avoiding the individual relationships and represented the causal maps using CLD software. In this research, a similar procedure was followed by using NVivo to analysis the data and using Vensim software to generate the CLD.

CLD is an effective tool used in SD modelling to analyse and develop an understanding of complex systems. It used to visualise how different variables in a system are connected. The diagram involves a set of nodes and loops. Nodes symbolise the variables and loops represent the connection between the two variables. Rabinovich & Kacen (2010) classified CLD relationships into contained, temporal, and causal. The influence of each variable on each other is represented by a positive or negative sign on the edge of each loop. In this research, two different pieces of software were used to facilitate this procedure, NVivo and Vensim software. NVivo was used to analyse and code the qualitative data while Vensim software was used to generate the CLD.

To sum up, the outcome of the final stage was the development of the PDRM model using CLD. Data was collected from a survey and interviews, and various methods were used to identify the parameters and variables. The analysis of the qualitative research using NVivo software and finally the mapping of the system and simulating the outcomes using Vensim software.

3.6 Ethical Considerations

Regarding the ethical considerations, all the participants in the study were treated according to the ethical guidelines of the University of Canterbury, for approval letter please check Appendix A. That not limited to secure the participants' acceptance before participating and the guaranteed of participants anonymity and confidentiality by using pseudonyms. In this study, each participant got a combination of letter and numerical code from 1 to 101; instead of their actual names to ensure their confidentiality. Also, the aim of the paper and information sheet to all participants was fully explained, and their participation was voluntary.

In addition, consents from the participants and their companies were provided to gain access to the necessary data. That has been documented by using an informed consent form for the participants and a letter from the confirmable sources to meet the Canterbury university ethical requirements for this research.

3.7 Summary

This chapter covered the methods adopted in this research. ST and SD approaches in conjunction with different analysis methods represented the core of this research methods to investigate post-disaster recovery systems. Based on a case study approach, the study used mixed qualitative and quantitative approach embodied by project data, survey, interviews and brainstorming sessions with construction and risk professionals from the case study as the source of data collection. The collected data has been analysed using the main analysis methods; AHP, QCA and STMs to answer the research questions and develop the main findings and the outcomes.

Chapter 4: Research Validation

4.1 Introduction

In the construction industry, risk management follows a Business As Usual (BAU) approach where risk factors mostly focus on internal and discrete risks within a steady working environment and are driven mainly by logical construction sequencing and methodology. In BAU, the regulatory environment is considered to be stable with low involvement of third parties such as insurance companies. After a disaster, the situation becomes quite different, which will be illustrated in the following sections.

This research validation chapter is representing the first step in ST, which aimed to discover opportunities and problems in the system. The validation stage is based on investigating the key differences between TRM practices, in construction projects, during BAU and the risk management practices in recovery projects after a disaster, herein defined as PDRM. Hence ISO3100:2009 risk management process is used as a standard of risk management in New Zealand; the justification was measured against it.

The main objectives of this chapter are to highlight the main differences between TRM and PDRM against the ISO31000:2009 process and illustrate the importance of having separate investigations in risk management for recovery projects. To determine the research questions that contributed to the development of the main research outcome, which is the PDRM model. The data collection has been done using initial interviews and brainstorming sessions with risk and construction professionals from the SCIRT programme.

4.2 The structure of this chapter

ST has been used as the basis of this chapter, using qualitative data collection to define the gaps and shape the research questions. Schieg (2006) mentioned that for risk management to be successfully installed in a project, there is a need for high-quality information to allow effective decision-making. Perera et al. (2009) highlighted that it is important in the risk management process, that involved parties adopt a learning approach. Previous projects are considered good real-life examples, which supports the idea of using SCIRT as a case study.

Figure 4.1 summarises the ST approach of the research validation stage and the development of the research questions. It consists of three phases, data collection, data analysis and outcome. To investigate the challenges of implementing TRM models in post-disaster projects, a qualitative approach was used based on two types of data collection techniques; semi-structured interviews and a brainstorming session. The choice of these techniques was due to its capacity of problem-solving and exploring new ideas. Semi-structured interviews give the participants the freedom to express their opinions and positions in their own terms and deliver a great chance for reliable, and comparable qualitative data (Currie, 2005). Brainstorming is one of the most well-known research methods for creative thinking (Al-khatib, 2012) and been used to identify the major differences between TRM and PDRM. According to Dunnette et al. (1963), brainstorming sessions are more effective in capturing quality ideas than individual data collection. Moreover, it has been identified as a valuable approach to data collection and auditing in risk management (Carpenter, 2007).

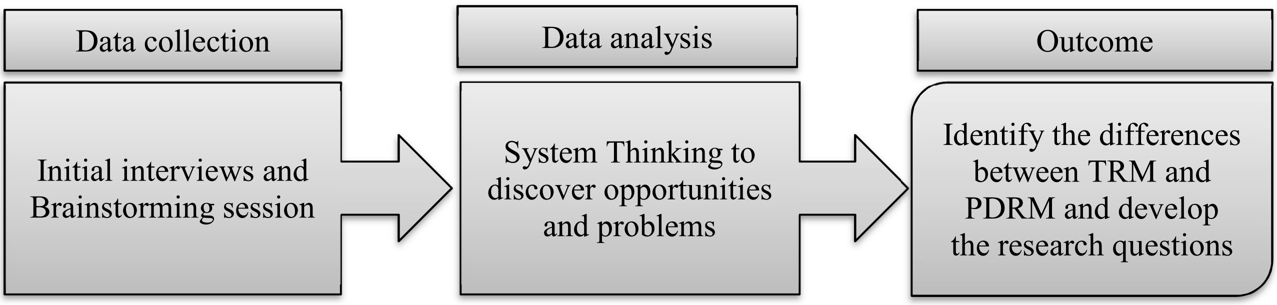


Figure 4.1: Summary of the System Thinking approach in this chapter.

The interviews were conducted with six members from the board and senior management team. The SCIRT board had eight members and the senior management team consisted of nine people and six were selected and invited to take part in the interviews. The selection consisted of professionals with construction experience. The interviewees had both intimate knowledge of the work procedures after the disaster, inside the SCIRT alliance, as well as from the work procedures in construction projects before the disasters. The six participants were selected from different management levels to capture a wider picture of the system. The selected participants included three from the SCIRT board. The other three came from the delivery teams. The interviews targeted the challenges of implementing TRM in post-disaster projects and identify areas for further investigation.

A brainstorming session was held to capture major differences between TRM and PDRM related to the ISO 31000 process. Fifteen project managers were randomly selected and invited from the delivery teams in SCIRT; all participants were directly involved in risk management procedure inside SCIRT (SCIRT, 2016). The brainstorming session included an explanation of the problem, presentation of the rules, the call for ideas, recording the ideas, elaborating on the idea and wrap up. Then the participants were divided into four groups to investigate the differences between TRM and PDRM.

After extracting the outcomes from the data collection stage, the differences between the TRM and PDRM were tabled and analysed to develop the research questions. Further details of the analysis are presented next.

4.3 Results

4.3.1 Semi-structured Interviews Results

The outcomes from the interviews are highlighted in the following points.

4.3.1.1 The Life cycle of recovery projects is different from traditional projects

Three participants declared that the life cycle of recovery projects in the construction industry is different from the life cycle of traditional projects in a normal environment because most of the recovery projects main phases happen concurrently due to the emergency and the prioritisation. Project definitions, concept design, detailed design, and project delivery phases in such instances are all interrelated and overlap at various stages. However, in traditional construction projects, the project lifecycle phases are often linear than concurrent in progression (see Figure 4.2).

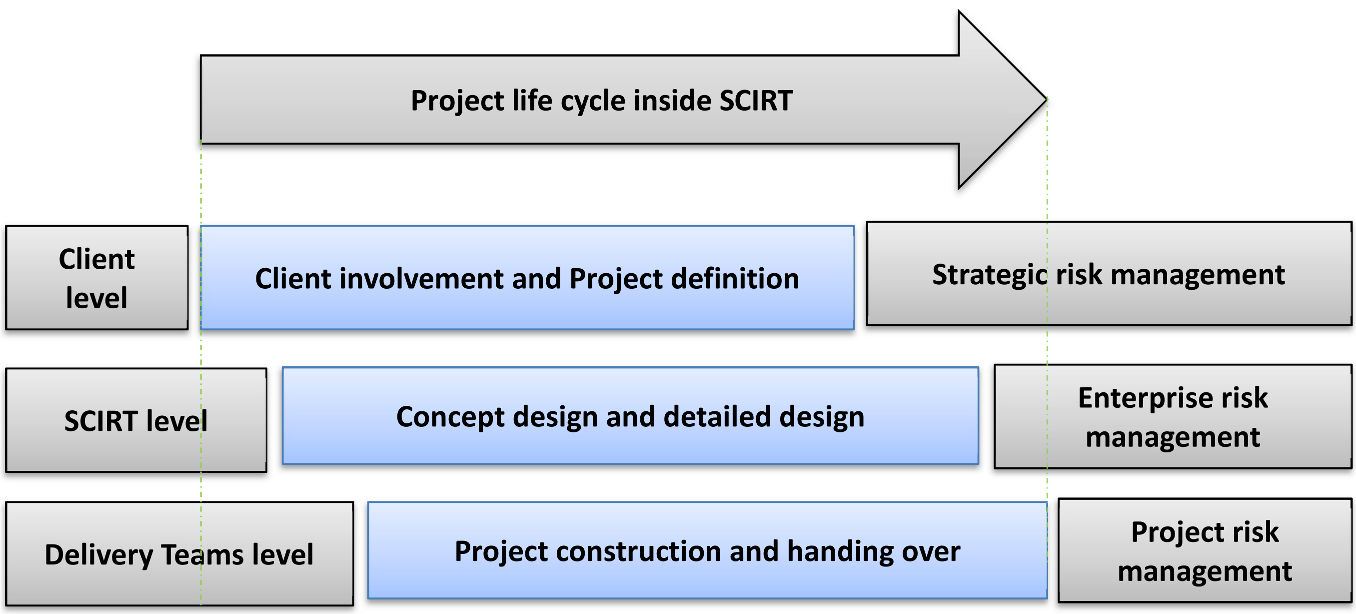


Figure 4.2: Risk management Levels inside SCIRT (SCIRT, 2015).

Traditionally in projects, the project scope would be well defined before starting the concept and detailed designs. This would then be followed by the project delivery and finally the handover. If any overlap exists between the various stages, it will be slight, however, in post-disaster recovery systems, the overlap is greater.

4.3.1.2 The lack of integration in risk management between different management levels

According to three participants, the complexity of post-disaster projects is higher than normal due to the interaction between project lifecycle levels. This complexity increases the risk profile, highlighting the importance of investigating critical risks in recovery projects. There is a lack of integration between the existing risk management levels. Some projects were designed and scheduled without taking into consideration the post-disaster risk factors because of the unforeseen and the unknown conditions of the ground after the earthquake. Three participants highlighted the importance of integration between the three levels of management in risk management. As a reflection from the participants' responses it became clear that to manage the post-disaster risks more efficiently, the integration of risk management between the three levels "SRM, ERM and PRM" became an important area for further research and investigation. This highlighted the need to check the critical risks and the dynamics between these different risk management levels, which shaped the first and second question.

4.3.1.3 TRM is not easy to implement after a disaster.

Despite ample available risk management studies in the construction industry, there is a concern regarding the implementation of these studies in real life. Two participants expressed their concern that TRM is hard to implement in recovery projects, and four participants declared that it is time-consuming. This is especially true in situations where emergency priorities drive most of the work. According to the interviewees, most of the previous studies are hard to follow with no easy applicable outcomes specific for post-disaster recovery systems. In an operational environment, the project delivery teams are often looking for best practices and a smooth risk management model that is not time-consuming, that is relatively easy and user-friendly to be used onsite, where they do not have a lot of time. Such issues make implement in post-disaster situations hard although some of these studies might be theoretically applicable. This raised the question to investigate the factors that could influence risk management performance in recovery projects.

4.3.1.4 Different market and culture after disaster.

According to two participants, the construction market in Christchurch was affected by the quakes, but even with the significant threats, some opportunities did arise. More opportunities arose when the rebuild of the city got underway. Participants remarked that there was an entrance of less qualified businesses into the construction market. Some non-construction companies changed their business strategy in order to join the construction sector to take advantage of the booming market after the earthquake despite not having (enough) experience in construction. The participants thought that the impact of earthquakes on the construction sector could vary between different countries due to several factors. For example, the cultural differences between countries can affect risk management practices when handling disasters. Also, there are differences in the standards and the level of engineering involved in the design. Moreover, projects can be affected by the construction methodology used during project execution. Therefore, it was essential to investigate the area of risk management in recovery projects and find the impact of the new market situation on risk management inside the recovery organisations.

Table 4.1 summarises the outcomes from the interviews. All the participants from the initial interviews believed that using TRM approach in post-disaster projects faced multiple challenges. These challenges were later elaborated on in the brainstorming section (Table 4.2). As it is observed from Table 4.1, the cost performance has been identified as a significant influencing factor to the risk management procedures inside SCIRT by all the participants. Conflict of interest between the three management levels has been mentioned four times as the second critical factor that influenced risk management. This highlighted the importance of a more detailed investigation into the variables that affect risk management in recovery projects. After the interview analysis of the case study SCIRT using the ST approach, the following areas have been identified for further investigations; the critical risks inside the recovery projects, the interaction between critical risks in the different levels of management, and the critical factors that could drive more effective risk management in recovery projects. These areas shaped the secondary research questions, which contributed to the development of the main research objective of creating the PDRM model.

Table 4.1: Interview outcomes summary

		Participants					
		Risk and opportunity manager	Senior estimator	Delivery manager	Delivery team leader	Construction manager	Deputy construction manager
Challenges of implementing TRM	Consuming time to apply and understand	✓	✓	✓			✓
	Hard to apply				✓	✓	
Factors driving risk management inside SCIRT	huge number of stakeholders involved		✓		✓		✓
	Unique alliance model	✓			✓	✓	
	Conflict of interest between levels		✓		✓	✓	✓
	Different concurrent levels	✓		✓			✓
	Schedule performance issues			✓	✓		✓
	Cost performance issues	✓	✓	✓	✓	✓	✓
Opportunities	Enough data inside SCIRT	✓					
	Different stakeholder culture		✓		✓	✓	
	Measure RMM		✓				✓

4.3.2 Brainstorming Session Analysis

The brainstorming session followed the interpretation of the existing data of the case study of "SCIRT" using the ISO 31000 process. ISO 31000:2009 breaks down the risk management process into three main stages: establishing the context, risk assessment, and risk treatment (Figure 2.1). These stages all involve effective communication, consultation, monitoring, and reviewing.

Fifteen project managers from SCIRT programme attended this brainstorm session. The session started with a presentation of the problem and the rules of the session. Then, the session participants were split into four groups, each group was asked to read through a paper with the same format as Table 4.2 and wrote down the differences between TRM and PDRM from their perspective against each risk management process as per ISO 31000:2009. This part lasted 30 minutes. During the next 15 minutes of the session, all the differences were highlighted and presented back to the four groups. There was strong evidence of the differences within each risk management stage. These are discussed in next section.

4.3.2.1 Establishing the context

Establishing the context is the first stage in the risk management process, according to ISO 31000:2009. This stage is vital in mapping out and planning the risk management process. Establishing the context stage is divided into strategic, organisational and risk management contexts. Such establishment involves identifying the stakeholders and their objectives, defining the risk assessment scope, and determining the evaluation criteria based upon organisation policy, goals, objectives and stakeholder interests (ISO 31000, 2009).

According to the brainstorming session, in PDRM, the working environment and the factors driving stakeholders are more complicated than TRM. In TRM, there is a limited number of stakeholders compared to the number of stakeholders in post-disaster projects. In PDRM, most stakeholders, including the public, media, and clients, are seeking a quick recovery from natural disaster events, thinking behind the benefits and more into public interest. Through this recovery procedure, the events might reach enormous dimensions and may be too big for the public sector to handle it on its own, which direct the risk appetite inside organisation higher levels.

4.3.2.2 Risk assessment stage

This stage includes risk identification, risk analysis, and risk evaluation. According to the brainstorming participants, in TRM, the workforce usually is available for the risk assessment stage. The risk identification is based on BAU hazard and with internal risk focus. The risk analyses focus on transferable risks. Likelihood of risk is low with less priority given to heritage and environmental risks. The risk evaluation mostly focusses on discrete risks.

In PDRM, the workforce is limited due to disaster. Risk identification mostly focusses on external risk factors that are out of control of anyone in the organisation, and the likelihood of these risks is high. Nevertheless, after a disaster, the main challenge in the risk assessment stage is to understand the current situation and assess what already exists. The United Nations Development Program (UNDP, 2010) called this step, Loss/Impact analysis. It includes identifying the nature, location, intensity and likelihood of major hazards prevailing in population, assets, and environment. This procedure is hard, expensive and time-consuming while it is crucial for PDRM.

4.3.2.3 Risk treatment stage

According to brainstorming participants, PDRM also differs because there is always a significant chance of secondary effect damages. This should be taken into consideration in risk treatment, such as aftershocks following a main earthquake or landslides that may continue after the main shift. Projects in PDRM are driven by emergency priorities; certain population groups may be more vulnerable than other groups in an emergency. There is a chance that the regulations need to be changed to address the potential new disaster scenarios by implementing changes in building codes and seismic retrofit after each earthquake. On the other hand, risk treatment options in PDRM are limited and more expensive when thinking about insurance and third-party involvement after a disaster. It is not always possible to find insurance due to the high uncertainties.

4.3.2.4 Communications

The management of the communication and knowledge of a construction project is an essential part of a successful risk management process in both TRM and PDRM. However, the amount of communication after a disaster is significantly higher due to the high level of interventions between all stakeholders, including the public, media, government, public and private sectors.

Furthermore, a communications plan after a disaster is always focused on reducing the impact of the disaster, improving people's knowledge about disasters and eventually changing people's attitudes towards risks. This process takes place through all available means of communication, including mass media, electronic media, postal, audio-visual, face to face, distributor print, and people (Van and Kingma, 2009). In TRM, the communication channels are less and clearer. In TRM there is less interaction with the public, leading to overall less emotional involvement while in contrast as mentioned in PDRM, the communication channels are more extensive, public relations are at their maximum potential, and the emotions reach high levels.

4.3.2.5 Monitoring and reviewing

Monitoring and reviewing stage includes risk control measures and records the significant findings within the risk assessment. From this perspective, the information related to risk assessment based on records becomes more significant. Tamura (2013) proposed a statistical model for analysing damage risks from recorded data. However, this stage is more complicated in PDRM as the project life cycles overlap. Due to the emergency, the project may start without completing bidding documents and even without getting signatures for approval.

In the TRM, the regulatory environment is more stable. Accordingly, monitoring and reviewing procedures of risks are more static in TRM; it could take longer to process and review. In PRM, the chance of a change in regulations is noticeable; monitoring and reviewing procedure is more dynamic with short review time while the likelihood of risk is high. The above discussion is summarised in Table 4.2.

Table 4.2: Differences between TRM and PDRM per phase as identified in ISO 31000(2009)

RISK MANAGEMENT PROCESS STAGE	*TRADITIONAL RISK MANAGEMENT*	*PDRM*
ESTABLISH THE CONTEXT	• Stakeholders: limited number representing number of sectors. • Objectives are profit and customer satisfaction focus • Stress is low • Public marginally involved • Media not or marginally involved • Time is not a critical factor for public and media if involved	• Stakeholders: Large number from different sectors including recovery/emergency management organization from natural disaster events, public, media, clients, etc. • Objectives are public, and humanity driven • Stress is high • Public heavily involved • Media heavily involved • Time is critical for a fast recovery from natural disaster events and emergencies
	• Risk Appetite is high with low risk environment	• Risk Appetite is low due to high-risk environment.
RISK ASSESSMENT	• Risk identification based on BAU hazards. • Workforce is available • Source of risk is internal focus • Likelihood of risk is low • Less involvement of heritage and environmental risks • Risk analysis focus on transferable risks. • Risk Evaluation focus on discrete risks	• Risk identification involve understanding and assess the current situation after disaster • Workforce is limited due to disaster • Source of risk is external focus • Likelihood of risk is high • High involvement of heritage and environment risks • Risk analysis involves Loss/impact analysis, which includes identifying the nature, location, intensity and likelihood of major hazards prevailing in population, assets, and environment. This procedure is hard, expensive and time consuming to be done accurately, however it is crucial for PDRM. • Risk Evaluation need to include emergency, and community driven prioritisation.
RISK TREATEMENT	• Low chance of secondary shocks. • Project driven by logic construction sequence and methodology. • Purchase insurance to cover risk is easy and cheap	• High chance of secondary effects damage such as secondary shocks after main earthquake. • Projects in PDRM are driven by emergency priorities. • Purchase insurance to cover risk is hard and expensive
COMMUNICATION	• Clearer and simpler interferences between stakeholders. • Public relations low • Low emotion involvement	• Complicated interferences between all stakeholders including public, media, government, public and private sectors. • Public relations high • High emotion involvement
MONITORING AND REVIWING	• Stable regulation environment. • Static most of the time • Long frequency review period (Marsh Risk Consulting, 2012)	• Huge chance of changing the regulations to fit the new disaster circumstances which vital in the communication plan • Ongoing and dynamic • Short frequency review period

4.4 Validity & Reliability

Last (2001) referred to the validity in the research market as the procedural accuracy and referred to the reliability as the study's success internally and externally. The study used ST and SD with different layers of analysis methods (AHP, QCA, and STMs) to break down the complexity of post-disaster systems to develop more effective and integrated risk management model used particularly in recovery projects after a disaster as there was a gap of investigating that in the academic library.

The study contributed to the research market by developing a PDRM model that could be used as a guideline by recovery organisations for more effective risk management in recovery projects. The model attends to be more practical than theoretical to overcome a high degree of complexity and the time and financial constraints inside the systems after a disaster.

The study also benefits the construction industry by offering an integrated picture of the drivers behind effective risk management in recovery projects by defining the critical risks, critical success factors, and the interaction between the risks in the different management levels using a post-disaster case study. That could provide more survival channels for some construction companies and help the workforce in the industry understand what their challenges, options and priorities regarding risk management after a disaster.

4.5 Summary

In this chapter, the ST approach has been used to discover and shape the research questions and validate the point of research through interviews and brainstorming sessions. The main differences between TRM and PDRM were highlighted. Managing construction risks under BAU circumstances where people are safe and have enough time for planning and building is very different from managing the risks after a major disaster such as an earthquake. In such circumstances, there is a large amount of uncertainty and projects can be influenced by political and media factors, third-parties insurances, emergency priorities and others. The chance for changing regulations for reflecting preparedness approaches during the disasters is enormous. The impact of events is potentially reaching to huge magnitudes, and a considerable chance of secondary effects of damages is rising dramatically. Almost all stakeholders are acting under pressure to recover as fast as possible from the disaster, that is why the management levels communicate heavily, and the work is often done concurrently.

In addition, the impact of disasters in risk management in recovery projects could fluctuate between companies and even different countries depending on various factors such as the country level of engineering, the used construction methodology and the country culture.

Considering all these complexities, further investigation of risk management practices is necessary to achieve effective integrated outcome based on a collaborative model reached between all management levels including government, designers and delivery teams in construction projects after disasters. The development of this model is shaped through investigating the critical risks inside the recovery projects, studying the interaction between these risks in the different level of management, and discovering the critical factors that drive more effective risk management in recovery projects.

The establishment of a specific PDRM model using ST and SD is valuable to break down the complexity in recovery projects. A model would enhance risk management efficiency in construction projects after disasters through building an integrated guideline between the different risk management levels.

Chapter 5: Critical Risks Inside Recovery Projects

5.1 Introduction

The need statement and the research questions were established in chapter 4. The first research question was to investigate the critical risks in recovery projects. This chapter has the objective to identify and critically analyse the risks associated with each level of management in the recovery projects. The critical risks inside a recovery project will be investigated using RII and AHP. The SCIRT alliance served as a case study. There were three levels of management in this case study, client level, SCIRT level and project delivery level (Figure 1.2). Surveys and interviews were used to collect data (See Table 3.1) which has been analysed using multiple-criteria decision analysis methods RII and AHP.

5.2 The structure of this Chapter

The research methodology consists of two parts, data collection and data analysis. For the data collection, a combination of quantitative and qualitative approaches has been used, with the help of a survey and interviews, respectively. The survey was used to rank the risk factors and the risk groups in the SCIRT programme. Risk factors refer to a list of high programme and project risks in SCIRT. All observed risks in the survey from the master risk register of SCIRT programme have been grouped into which called risk groups based on its impact. These risk groups are financial risks, schedule risks, quality risks, scope risks, safety & environment risks, and macro risks. Macro risks are legal, political and social risks (Hastak & Shaked, 2000).

The interviews were held to verify the survey outcomes and to find any additional risks from the participant's perspective. The selection of the participants was made to ensure their involvement in the risk management practices inside SCIRT. The data from the survey and the main interviews is presented in Table 3.1. The survey targeted in specific sections the inputs for RII and AHP. RII was used to rank the risk factors that influenced the entire SCIRT programme of work to identify the critical risks. AHP was used to investigate the risk groups in each separate management level (See Figure 5.1).

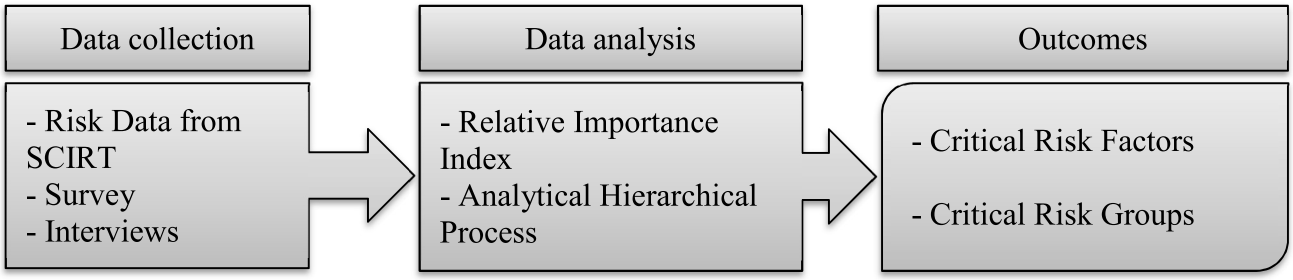


Figure 5.1: Flow diagram of the chapter.

5.2.1 Relative Importance Index

Relative Importance Index (RII) is an effective method of ranking used in research to endorse the decision-making process. It is a good way to evaluate the relative importance of a variable in a pool of similar items (Holt, 2014). RII was used to rank the risk factors in the whole programme of SCIRT using the collected data from the participants to identify which factors are more critical inside post-disaster recovery system.

In the survey, participants were given a list of high risks from SCIRT programme. This list of high risks was developed after exploring the programme risk register, and several projects risk registers inside SCIRT. The programme risk register represented all higher-level risks facing SCIRT, while the individual project risk registers contained the project-specific risks. The participants were asked to rank which risks based on their significance to the overall programme and project success. Participants had the opportunity to add risks to the list using an edit box. Only the ten top-ranked risks were chosen as it usually enough to cover most of the critical risks in a project and to align with previous studies similar to Zou et al. (2006), Tam et al. (2004), and McIntosh and McCable (2003).

Calculations for defining RII for each factor were performed according to the following formula (Hosseini et al., 2016).

RII= $(1n_1+2n_2+3n_3+4n_4+\ldots..10n_{10})/(A*N)$ (1)

Where:

- $n_1, n_2 \ldots n_{10}$ are participants' response scale from 1 to 10.
- N is the total number of respondents for each factor
- In addition, A is the largest scale range (10 for this analysis to match the survey scale in appendix B).

5.2.1 Analytic Hierarchy Process (AHP)

AHP is used for the second layer of investigation to identify the critical risk groups at each management level. The process of AHP includes structuring the hierarchical structure of factors, collecting the data through survey and interview; pairwise comparison of each risk group; rank optimisation of each risk group (Sharma & Pratap, 2013), and evaluation and analyses of the alternative combinations.

As it was mentioned previously in the literature review and research methods chapters, the AHP structure includes objectives, main criteria and sub-criteria. In this research, the objective is to find the critical risk groups inside each management level of SCIRT. The main criteria are the levels of management, and the sub-criteria are the risk groups (see Figure 5.2).

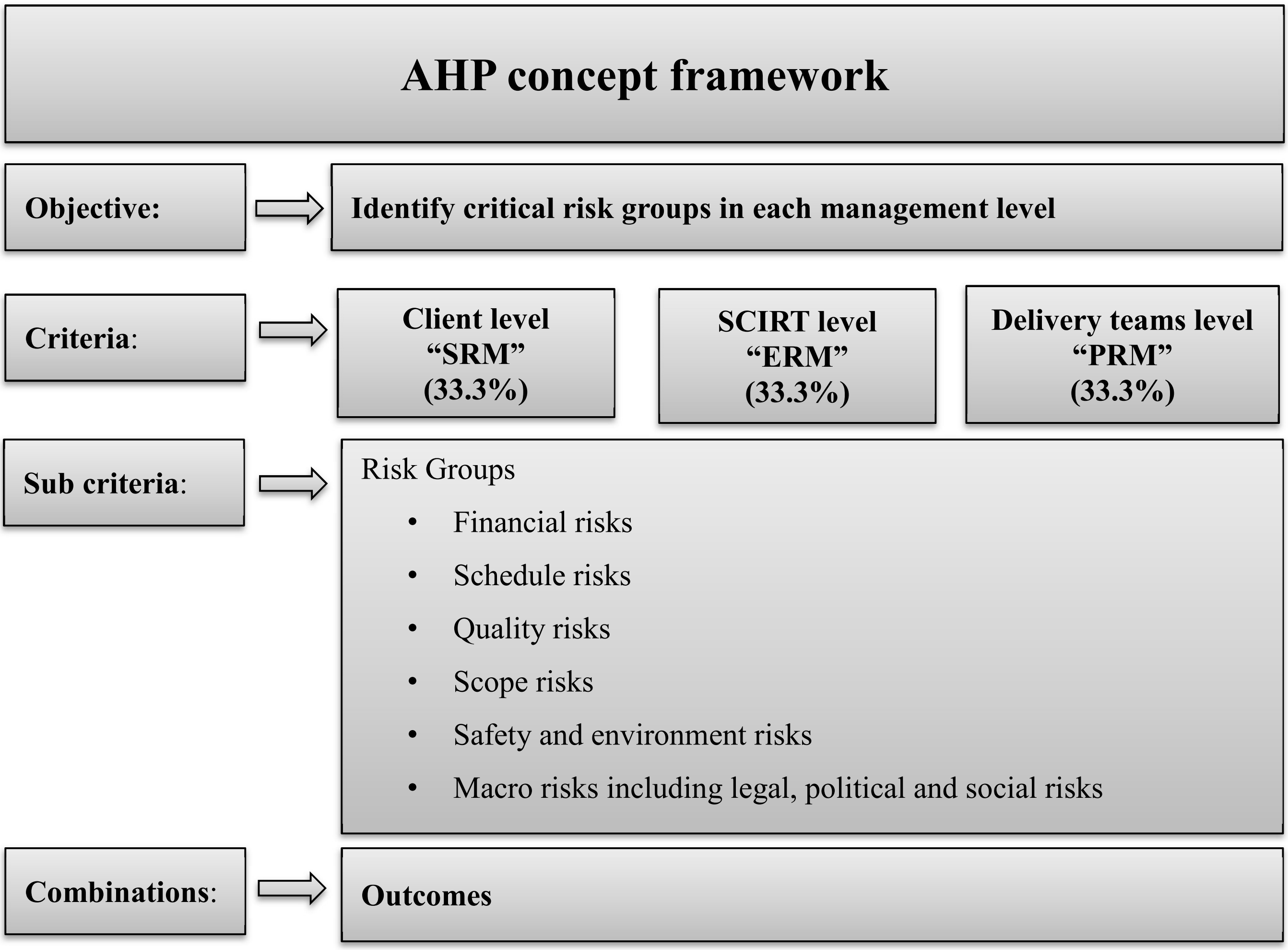


Figure 5.2: AHP structure in this study.

As it could be seen in Table 3.1, 75% of the survey participants were from delivery teams level, 15% were from SCIRT level, and 10% were from the client level. It is normal to see the majority of the participants from delivery team, however, to avoid the majority effect and the bias to any management level over another, the main criteria level has been allocated an equal share of 33.3% each. Figure 5.3 shows an example of how the weights in the main criteria level could impact the results in the sub-criteria level in AHP. For the client level, if the financial risks score is 13, this score would be reconciled and multiped by the weight of client level "10%" which would reduce the score of the financial risks in client level to 1.3 as per the below example.

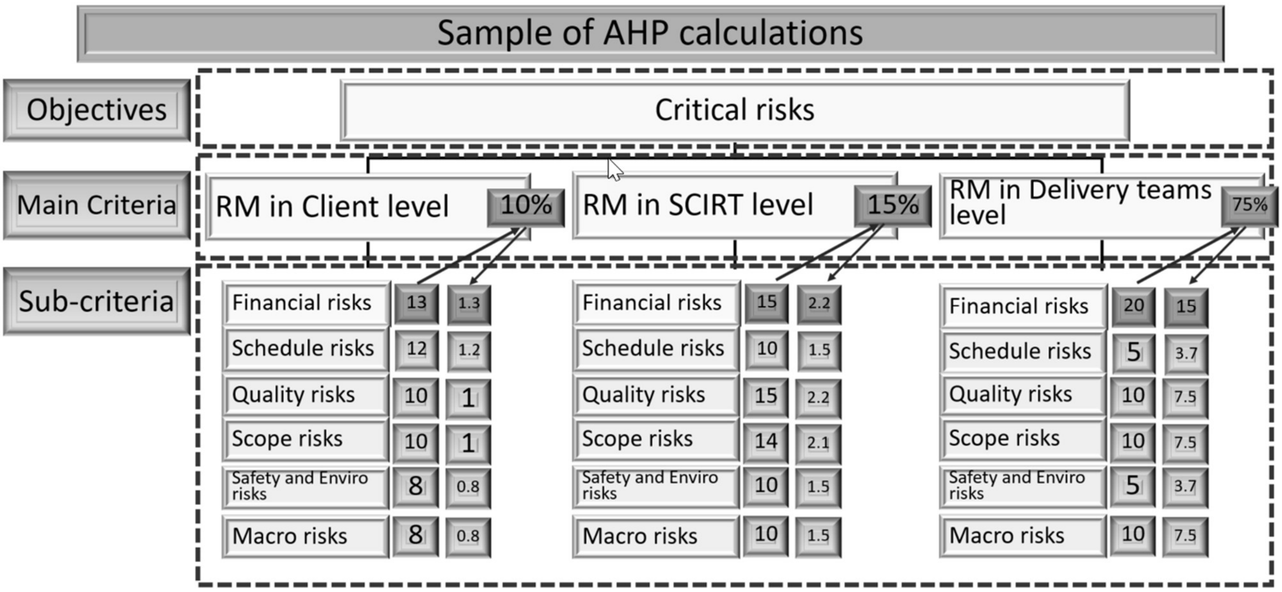


Figure 5.3: An example of financial risk calculations according to AHP.

Participants in the survey have been asked to rank the risk groups based on its importance to the project success under each management level. Then, the data has been arranged into a matrix and the normalised principal Eigenvector of the matrix has been calculated using the AHP calculator that was developed by Goepel (2013). Figure 5.4 represents one sample of the generated matrix from the AHP calculator.

Matrix		1 Budget risks	2 Schedule risks	3 Safety and Enviro risks	4 Quality risks	5 Macro risks	6 Scope risks	normalized principal Eigenvector
Budget risks	1	-	1 5/8	5/8	4/5	1	1 7/9	17.70%
Schedule risks	2	3/5	-	3/5	1 1/8	1	1	13.88%
Safety and Enviro risks	3	1 4/7	1 5/8	-	1 5/6	2 1/2	1 1/9	25.06%
Quality risks	4	1 2/9	8/9	1/2	-	1 2/9	1	15.51%
Macro risks	5	1	1	2/5	4/5	-	1 1/5	13.83%
Scope risks	6	4/7	1	8/9	1	5/6	-	14.02%

Figure 5.4: Sample of the matrix.

More detailed of AHP worksheets could be found in Appendix D

5.3 Results

The following section contains the analysis for both decision-making methods, RII and AHP and including the main outcomes from both techniques.

5.3.1 Ranking of Critical Risks Inside SCIRT

Table 5.1 summarises the results of the RII analyses of the risk factors based on the inputs from the survey that have been done with the participants.

Table 5.1: RII analyses of the critical risk factors all-over SCIRT programme.

Ranking	*Risks*	*RII*
1	*Inexperienced staff*	*74.13%*
2	*Low management competency*	*66.17%*
3	*Poor and inconsistent communication*	*63.85%*
4	*Scope uncertainty*	*63.33%*
5	*Timing of strategic decisions not aligning with schedule demands*	*62.89%*
6	*Incomplete approval and other documents*	*62.50%*
7	*Excessive approval procedures in administrative government departments*	*61.00%*
8	*Overlapping or conflict of authorities*	*59.52%*
9	*Tight project schedule*	*59.40%*
10	*Disruption in the community*	*59.34%*
11	*Lack of funding effects priorities / strategy*	*58.36%*
12	*Variations to the scope*	*58.29%*
13	*Lack of coordination between project participants*	*56.89%*
14	*Political intervention into Program*	*56.44%*
15	*Lack of unity between stakeholders*	*55.91%*
16	*Inadequate or insufficient site information (soil test and survey report)*	*54.50%*
17	*Lack of resources*	*54.00%*
18	*Lack of clarity of standards arising from laws*	*53.61%*
19	*Community demand for information*	*52.00%*
20	*Serious noise pollution caused by construction*	*47.80%*
21	*High performance or quality expectations*	*47.14%*
22	*Changes to legislation*	*45.17%*
23	*Price inflation of construction materials*	*44.50%*
24	*Competitive Tension between Delivery Teams - Adverse effects*	*43.61%*
25	*Continuity of natural hazard (Seismic activity, land settlement, floods, etc.)*	*42.85%*
26	*Insurance cover difficulties*	*40.84%*
27	*Change of Government*	*36.17%*

The replies from the participants showed that inexperienced staff was the highest critical risk (RII= 74.13%) with a large gap between it and the second critical risk, which is the low management competency (RII=66.17%). The large difference shows that the dominant opinion between all the participants in the three-management level was the risk of inexperienced staff was one of the top risks in recovery projects. Poor communication was found to be the third highest risk (RII = 63.85%). This highlights the importance of having effective communication in recovery projects. The fourth highest rating with RII=63.33% was for the scope uncertainty risk and in fifth position with RII=62.89% was the risk that the timing of strategic decisions did not align with schedule demands. Although the results show that some risks have RII values that appear close together, the difference still represents a differentiation.

The survey participants were given the opportunity to add more key risks to the list by using an edit box. A web-based tool attached to survey engine Qualtrics was used to analyse these inputs and create a word cloud from them. The larger the word is in the cloud, the more frequently the word was put forward. Specific risks were highlighted as key risks based on its high appearance frequency in the edit box. The risks that were mentioned more often were lack of resources, inexperienced staff and rework (Figure 5.5).

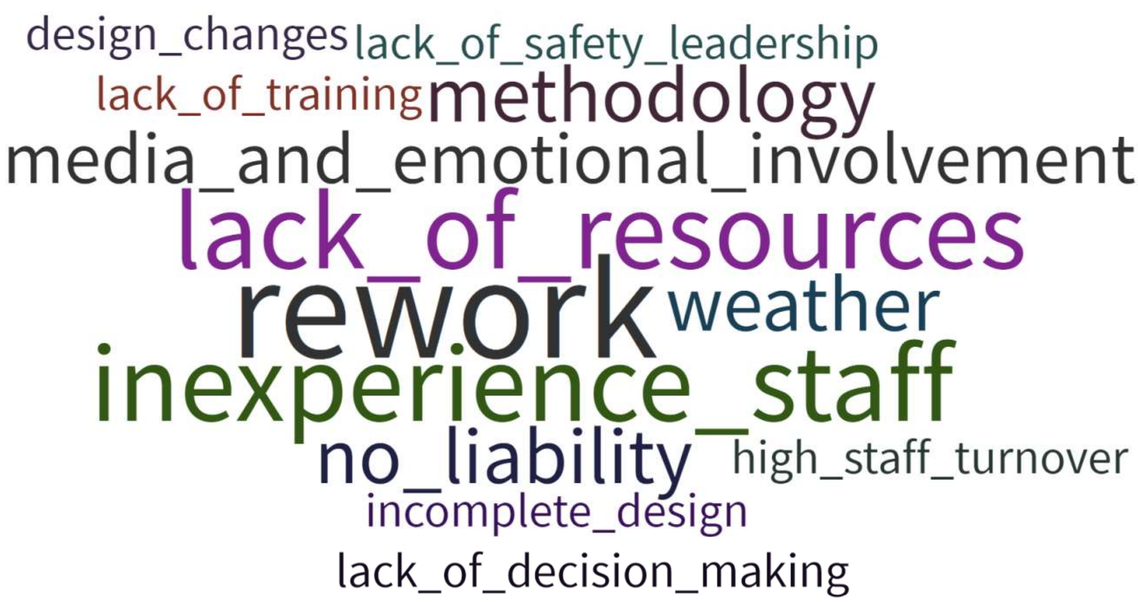


Figure 5.5: Word cloud of the added risks from survey respondents, font size increase with the frequency of mentioning.

With further discussion with the interview participants, they have explained that the cause of these risks is due to the lack of resources after the earthquake as many people moved out from Christchurch and left the market short in resources. Statistics New Zealand (2012) showed a large inflow of international migrants to work in the Canterbury region to fill this gap with the huge work programme ahead. Although some of the newly immigrated staff were theoretically qualified, they had no relevant experience with the New Zealand industry. Consequently, due to high time pressure, there was limited opportunity to train new staff. This affected the quality of the work and increased rework. This lack of competency was also a common source of poor quality work delivered by some local subcontractors that were hired by SCIRT. As it has been mentioned earlier, some companies, due to the earthquake and to take the advantage of the market situation; changed their core business to construction with no enough experience.

5.3.2 Analytical Hierarchical Process (AHP) Results

Table 5.2 shows the ranking of each risk type at the different management levels inside the SCIRT programme. At the client level, the financial risks have the highest score with 7.7%, followed by safety and environment at risks with 7.3%, then quality risks with 6.3%. At the SCIRT level, safety and environment-related risks have the highest score with 7.5%, followed by quality-risks with 7.3% then financial risks with 5.6%. At the delivery team level, safety and environment risks are the highest with 10.9% followed by financial risks 5.7% then quality risks with 5.7%.

Table 5.2: Criteria and Sub Criteria for AHP Analysis.

	CRITERIA	CLIENT LEVEL 33.3%	SCIRT LEVEL 33.3%	DELIVERY TEAMS 33.3%
SUB CRITERIA	Financial risks	**7.7%**	5.6%	5.7%
	Schedule risks	4.5%	4.5%	4.9%
	Quality risks	6.3%	7.3%	5.7%
	Scope risks	3.7%	4.4%	3.4%
	Safety and Enviro risks	7.3%	**7.5%**	**10.9%**
	Macro risks	3.8%	4.1%	2.7%

Table 5.2 shows a clear gap between first and second risk group, which shows the real awareness of the importance of the safety and environment risks in the delivery side in recovery projects.

The final stage in AHP is to evaluate the alternatives and determine the combination with the highest ranking. The results of the previous steps, Table 5.2, provide the inputs of the evaluation stage. The combination ranking is the sum of the individual ranking of the risk groups in a raw. The combination with the highest score is suggested as the most used combination in the recovery system based on the inputs from participants survey. Table 5.3 shows the ranking of each risk group in the three levels of management inside the case study and the highest six ranking combinations.

Table 5.3: Models of risk groups in Recovery Projects.

Alternatives	Client level	%	SCIRT Level	%	Delivery Teams	%	Model Rating
Combination 1	Financial risks	7.7%	Safety and Enviro risks	7.5%	Safety and Enviro risks	10.9%	26.1%
Combination 2	Financial risks	7.7%	Quality risks	7.3%	Safety and Enviro risks	10.9%	25.9%
Combination 3	Safety and Enviro risks	7.3%	Safety and Enviro risks	7.5%	Safety and Enviro risks	10.9%	25.7%
Combination 4	Safety and Enviro risks	7.3%	Quality risks	7.3%	Safety and Enviro risks	10.9%	25.5%
Combination 5	Quality risks	6.3%	Safety and Enviro risks	7.5%	Safety and Enviro risks	10.9%	24.7%
Combination 6	Quality risks	6.3%	Quality risks	7.3%	Safety and Enviro risks	10.9%	24.5%

As can be seen from Table 5.3, combination 1 has the highest value for the combination rating (26.1%). The number comprises of the financial risks with the highest percentage in client level with 7.7%, and the Safety and Environment Risks from both SCIRT Level and the Delivery Teams Level with rating percentage of 7.5%, 10.9% respectively. Combination 2 comes in the second with high financial risk for the client, quality for SCIRT and safety and environment for the delivery teams. Combination 3 shows the priority of safety and environment risks through the three management levels.

Looking through the top combinations, some specific risk groups have been mentioned with higher frequency than others. For example, safety and environment risks have been mentioned eleven times, quality risks have been mentioned five times, and financial risks have been mentioned two times. This highlights the prioritisation of these risk groups in post-disaster projects from the participant perspective. It also shows the importance of taking significant actions towards mitigating or reducing these risks in recovery projects.

5.4 Summary

This chapter aimed to improve the understanding of critical risks at each management level in recovery projects to endorse effective risk management in post-disaster.

Critical risks in recovery projects have been investigated using SCIRT case study within its three levels of management, client, SCIRT and delivery teams. The research explored the experience of construction and risk professionals in recovery projects using two ways of data collection, questionnaire and face to face interviews. The data has been analysed using RII and AHP methods. RII was used to rank the Risks Factors inside the whole programme, while AHP was used to rank the risk groups inside each management level. Both methods were used to support the decision making of finding critical risks for recovery projects.

After investigating the risk factors, it has been found that inexperienced staff, low management competency, poor and inconsistent communication, scope uncertainty, and timing of strategic decisions not aligning with the schedule demands are the key risk factors in recovery projects. The identified risk groups are financial risks, schedule risks, quality risks, scope risks, safety and environment risks and macro risks, which include legal, political and social risks. Most of these risks are due to the earthquake disaster. Lots of people had moved, leaving the construction market in need of staff. To cope with the volume of work, the recovery organisations hired inexperienced staff, especially in terms of the local language, culture and market. This led to a lack of communication and affected the quality of work negatively.

After investigating the three levels of management of SCIRT, combination 1 were financial risks in client level, and safety and environment risks in both management programme and delivery teams are considered the most important risk groups in recovery projects. In other words, it has been found that at the strategic level, financial risks are the highest in the client level as the client was looking to secure funding to the recovery projects. However, both programme and project levels (SCIRT and Delivery Team level), the safety and environmental risks were given the priority to secure the public and environment safety after a disaster and avoid the emotional, reputational and media stresses.

It is essential to consider front facing and upfront risk management plan for the above risk factors and risk groups when dealing with recovery projects for more effective risk management and to avoid any delays and setbacks.

Chapter 6: Interactions and Dynamics of Risks in Recovery Projects

6.1 Introduction

This chapter investigates the interactions between risk groups throughout the different management levels in recovery projects using STMs in conjunction with QGT (Figure 6.1). These interactions are a two-directional relationship which defines the influence of risk groups on one another and inside the recovery system.

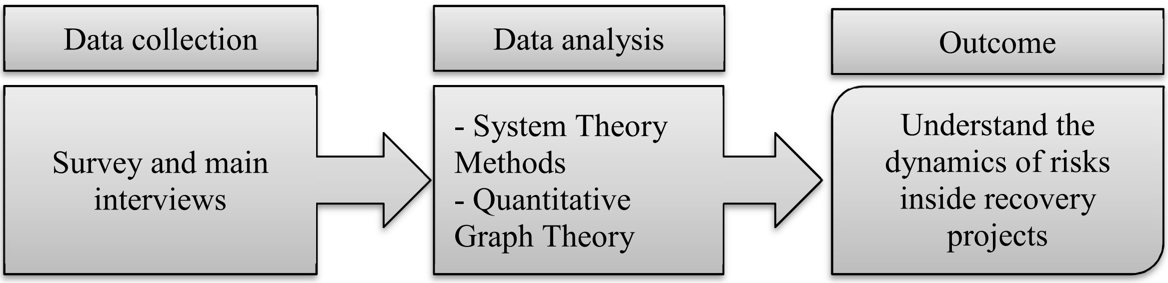


Figure 6.1: Frame diagram of the chapter.

6.2 System Theory Methods and Quantitative Graph Theory

The used methodology in this chapter is an adaptation of the work from Buerki (2006) and Skoko (2013). Table 6.1 shows the steps that Buerki and Skoko used in the first 2 columns. The third column contains the adaption in present research.

STMs can evaluate complex and dynamic systems by exploring the interacting components with the system to understand the systems better. The first stage in STMs is to identify problems and opportunities. The problem has been defined through the initial investigations and the research validation “Chapter 4” by developing the research questions.

STMs have been used to investigate the interactions and dynamics of the risk groups between the three risk management levels inside the SCIRT programme.

The second stage is to reflect wholeness by conducting holistic structure and potential tests (Buerki, 2006). According to Skoko (2013), the holistic structure test is one of STMs tools used to enable a quick holistic check of the system to point out any missing items or blind risks. In this research, the holistic structure test has been conducted on the SCIRT risk register using a survey and interviews with participants to identify any missing risk groups.

Table 6.1: STMs as per Buerki (2006) and Skoko (2013) vs. the present study.

STMs Stages (Buerki, 2006)	Tools of STMs (Skoko, 2013)	Implementation in this study
1. Discover and identify opportunities and problems	Brain-writing and rich picture drawing	Investigations and develop the research questions
2. Reflect wholeness	Holistic structure test & Holistic potential test	Review and grouping of risks under appropriate drivers
3. Work out possibilities to define the interactions	Systemic gap-analysis	Scale the risks (0 to 4) by conducting a survey.
4. Reflect interrelations	Double-cross-impact analysis	Represent the interrelations using QGT to create the impact matrix
5. Understand the dynamics	Map of interactions	Construct the Map of Interactions using Vensim software.

Then risks were grouped under appropriate drivers. Buerki (2006) described this step as the holistic potential test. In this step, the risks were grouped to a set of relevant key groups based on their impact on the SCIRT programme. The risks in SCIRT have been divided into six groups: financial risks, schedule risks, quality risks, scope risks, safety and environmental risks, and macro risks. Table 6.2 shows the key risk groups that have been identified in the three management levels (Client, SCIRT, and Delivery Teams) for the survey and the interviews.

This grouping procedure is meant to make the survey more practical and reduce the matrix size and to be applicable for the Double-Cross-Impact Analysis.

Table 6.2: Critical risk groups and acronyms.

Risk group ID	Description
Fin_Client	Financial Risks Client Level
Fin_SCIRT	Financial Risks SCIRT Level
Fin_DT	Financial Risks Delivery Team Level
Sch_Client	Schedule Risks Client Level
Sch_SCIRT	Schedule Risks SCIRT Level
Sch_DT	Schedule Risks Delivery Team Level
Qlty_Client	Quality Risks Client Level
Qlty_SCIRT	Quality Risks SCIRT Level
Qlty_DT	Quality Risks Delivery Team Level
Sco_Client	Scope Risks Client Level
Sco_SCIRT	Scope Risks SCIRT Level
Sco_DT	Scope Risks Delivery Team Level
Saf_Client	Safety and Environmental Risks Client Level
Saf_SCIRT	Safety and Environmental Risks SCIRT Level
Saf_DT	Safety and Environmental Risks Delivery Team Level
Mcr_Client	Macro Risks Client Level
Mcr_SCIRT	Macro Risks SCIRT Level
Mcr_DT	Macro Risks Delivery Team Level

QGT was used to identify the interactions and the relations between the risk groups in the system. König (1935) offered the Graph Theory (GT) to the research market as a descriptive approach for visualising variables and links between these variables using graphs.

Figure 6.2 shows different categories of GTs available in the research market, including Algebraic Graph Theory, Spectral Graph Theory, Topological Graph Theory and the Random Graph Theory as descriptive methods. Dehmer et al. (2017) clarified the QGT as a branch of graph theory and network science. They defined QGT as the quantification of structural data of graphs rather than the descriptive structure in classic GT. They also demonstrated the importance of the use of QGT in future research and its value in analysing the context and the data of networks and systems. Nevertheless, QGT has many applications in various scientific areas such as using web algorithms in PageRank (Page et al., 1999) and analysing properties of social network analysis (Wasserman & Faust, 1994).

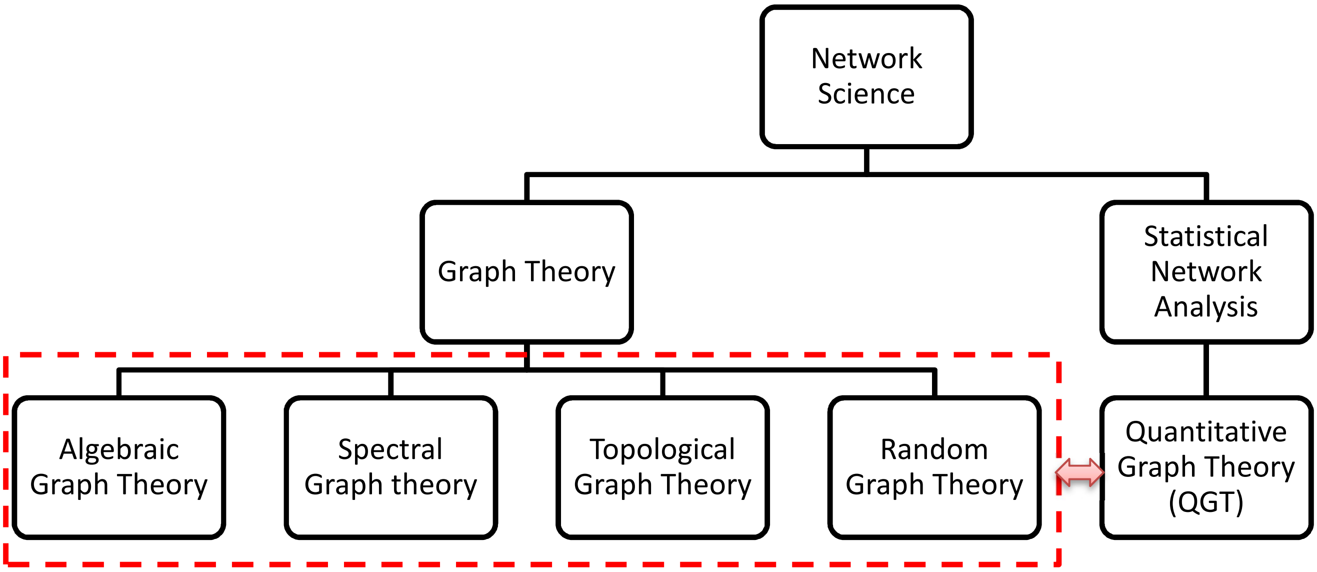


Figure 6.2: The graph theory as a branch of network science (Dehmer et al., 2017).

The QGT process in this research included creating the impact matrix and developing the map of interactions from this matrix. The matrix was used to facilitate the systematic assessment of the relationship between each risk group. Vester and Hesler (1980) developed the double-cross-impact analysis in order to assess all interrelations between the different factors in dynamic systems, and successfully evaluated key factors for clarifying and improving all varieties of systems. Later, in 2000, Messerli used it to investigate the impact strength of each factor in dynamic systems based on Advanced Input Analysis (AIA).

The third stage in STMs is to define the interactions. A survey was conducted to collect the participants' inputs of how each risk group interacts with the other. The participants were asked to choose the top two risks in each management level, then fill in an impact matrix between the chosen risk groups. The survey results are depicted in an impact matrix. The impact matrix is an adjacency matrix taking the risk groups (shown in Table 6.2) as variables. The rows and columns of the matrix represent vertices for the map of interactions.

In order to understand the impact of a key risk group on another one, an estimation of interrelations between key risk groups was carried out using metric measures. The value “4” represents the highest interaction, whereas a “0” represents no interaction. Table 6.3 presents the scoring in the impact matrix.

Table 6.3: Scoring ranking of the impact matrix

No interaction	0
Weak interaction	1
Medium interaction	2
Good interaction	3
Strong interaction	4

In the impact matrix, the sum of each line for each risk group is the Active Sum (AS). It represents the total interaction which that risk group exists on the system. Table 6.4 shows the impact matrix from one of the participants to illustrate how the data was collected in the survey.

Table 6.4: Sample of impact matrix from the survey

Risk groups	Mcr_Client	Fin_Client	Saf_SCIRT	Sch_SCIRT	Saf_DT	Qlty_DT	Sum
Mcr_Client	4	3	0	1	0	2	10
Fin_Client	3	4	1	3	1	3	15
Saf_SCIRT	0	1	4	2	4	2	13
Sch_SCIRT	1	3	2	4	2	2	14
Saf_DT	0	1	4	2	4	2	13
Qlty_DT	2	3	2	2	2	4	15
Sum	10	15	13	14	13	15	

The fourth stage in STMs is to reflect interrelations. After extracting all the impact matrices from the participants’ inputs, a combined impact matrix was created for the top risk groups (Table 6.5).

Table 6.5: The combined impact matrix, showing the strength between the risk groups interactions

Risk Groups		ID																	
ID	**label**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	**Sum**
1	**Fin_Client**	4	4	2	2	0	1	1	1	2	1	2	1	1	2	1	1	1	1	28
2	**Fin_DT**	4	4	2	2	0	1	1	1	1	1	1	1	1	3	1	1	1	2	28
3	**Fin_SCIRT**	2	2	4	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	21
4	**Mcr_Client**	2	2	1	4	0	1	0	1	1	0	0	1	1	1	1	1	1	1	19
5	**Mcr_DT**	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	4
6	**Mcr_SCIRT**	1	1	0	1	0	4	1	1	1	0	0	0	1	1	1	1	1	1	16
7	**Qlty_Client**	1	1	1	0	0	1	4	1	1	0	0	1	1	1	1	1	0	1	16
8	**Qlty_DT**	1	1	1	1	0	1	1	4	1	0	0	0	1	1	1	1	0	1	16
9	**Qlty_SCIRT**	2	1	1	1	0	1	1	1	4	1	0	1	1	1	1	1	1	1	20
10	**Sco_Client**	1	1	1	0	0	0	0	0	1	4	1	1	1	1	0	0	0	0	12
11	**Sco_DT**	2	1	1	0	0	0	0	0	0	1	4	1	1	0	1	1	1	1	15
12	**Sco_SCIRT**	1	1	1	1	0	0	1	0	1	1	1	4	1	1	0	1	1	1	17
13	**Saf_Client**	1	1	1	1	0	1	1	1	1	1	1	1	4	1	1	1	0	0	18
14	**Saf_DT**	2	3	1	1	0	1	1	1	1	1	0	1	1	4	2	1	0	1	22
15	**Saf_SCIRT**	1	1	1	1	0	1	1	1	1	0	1	0	1	2	4	1	0	1	18
16	**Sch_Client**	1	1	1	1	0	1	1	1	1	0	1	1	1	1	1	4	1	1	19
17	**Sch_DT**	1	1	1	1	0	1	0	0	1	0	1	1	0	0	0	1	4	1	14
18	**Sch_SCIRT**	1	2	1	1	0	1	1	1	1	0	1	1	0	1	1	1	1	4	19
	Sum	28	28	21	19	4	16	16	16	20	12	15	17	18	22	18	19	14	19	

In the combined impact matrix, the values represent the strength of the link between the risk groups. As mentioned earlier, the sum of each row or column represents the degree of the vertex, which indicates the interaction degree of this risk group in the system. The higher the sum, the stronger the presence and the interaction of this risk group in the system. As the values indicate the interaction, the column values for each risk group are identical to the column values below that same risk group (ID). Another way of showing the data from the combined impact matrix and its influence on the system is the radar chart. The radar chart in Figure 6.3 shows the degree of interaction between each risk in the system. It has been generated using Microsoft Excel. The number in front of the risk group represents the ID from the combined impact matrix, and the number at the end represents the value of the sum.

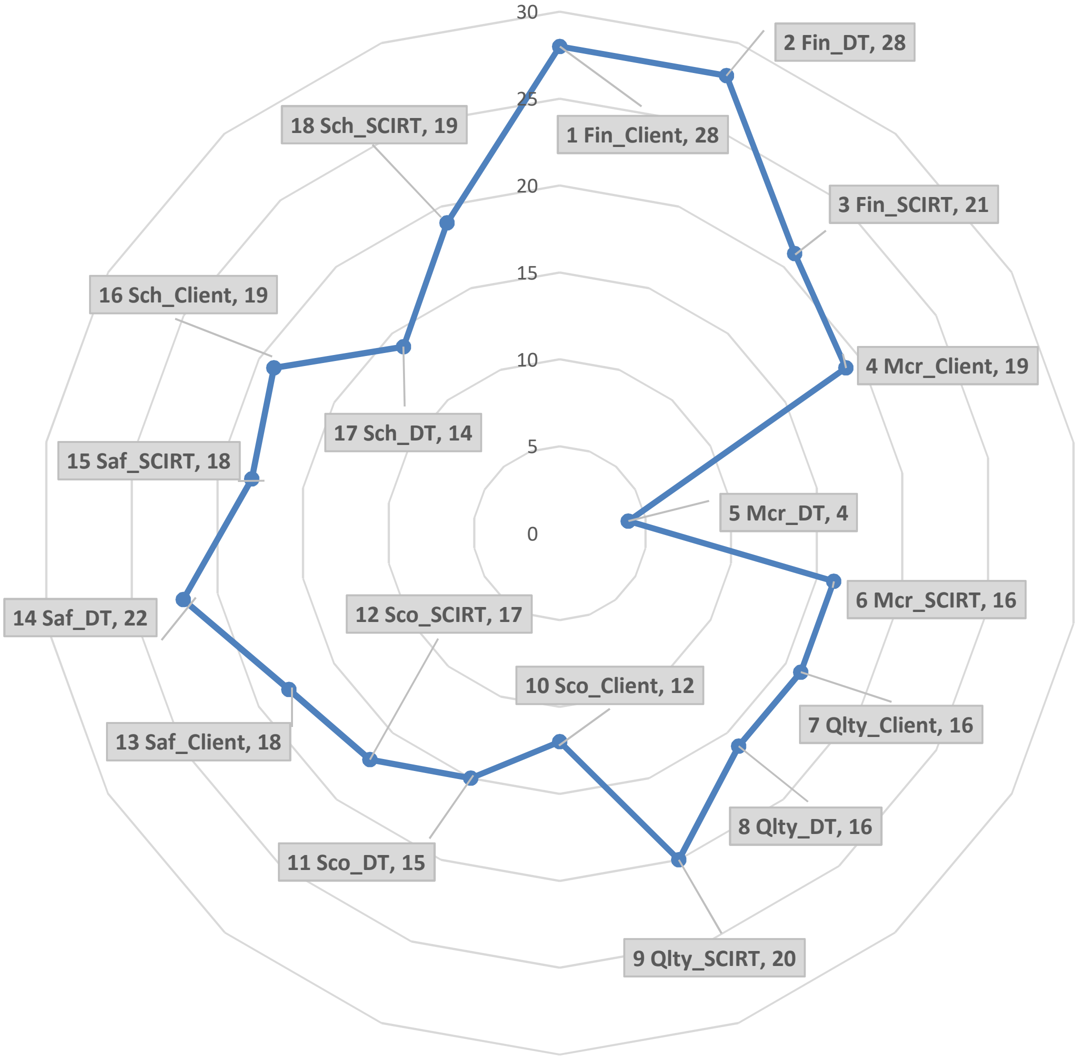


Figure 6.3: Radar chart for risk groups inside SCIRT.

The chart shows that Fin_Client and Fin_DT have the highest impact on the recovery system with a score of 28, followed by Saf_DT with a score of 22. It means survey participants believed that financial risks in both client and delivery team levels were key risks inside SCIRT case study. After discussing that with the interviewed participants after the survey, they clarified that SCIRT had recognised that from the beginning of the recovery programme. The client tried to increase the trust with the delivery teams by communicating to them that the funding for the recovery work was available, which attracted them to come back to the disaster area and work in the recovery programme.

The safety and environmental risks in delivery teams are in third place to impact the recovery system, as the safety of people is most important as was identified in the previous chapter. On the other hand, the micro risks group for the delivery team represented the lowest impact on recovery systems.

The participants clarified that delivery teams could deliver any project as long as the funding was secured. The final stage in STMs is to understand the dynamics by developing the map of the interactions between the risk groups in SCIRT. The map of interaction was used to understand the dynamics among variables by creating a virtual picture of the interrelation (Kanshieva, 2012). Based on the QGT, the combined impact matrix could be used to create the map of interactions between all risk groups represented as a network diagram. The nodes are the risk groups, and the lines between the nodes represent two directional connections and interactions between these risk groups in the system. The thicker the lines, the stronger the level of interaction; also, colour-coding has been used to easily track the interactions where:

- Red colour refers to a strong level of interaction with a score of 4
- Blue colour refers to a good level of interaction with a score of 3
- Green colour refers to a medium level of interaction with a score of 2
- Grey colour refers to a weak level of interaction with a score of 1
- No lines refer to no interaction with a score of 0

Figure 6.4 represents the map of interaction that was generated using Vensim software version 7.2. The numbers inside the nodes are risk-group IDs, which are represented in Table 6.5. These IDs also represent the number of variables used in the matrix and the map of interaction. For more clarity, interactions in this map are represented by lines which indicate a two-directional relationship between risks.

Note: To avoid loops inside Vensim software while drawing the map of interaction, the diagonal figures of the matrix must be set to zero.

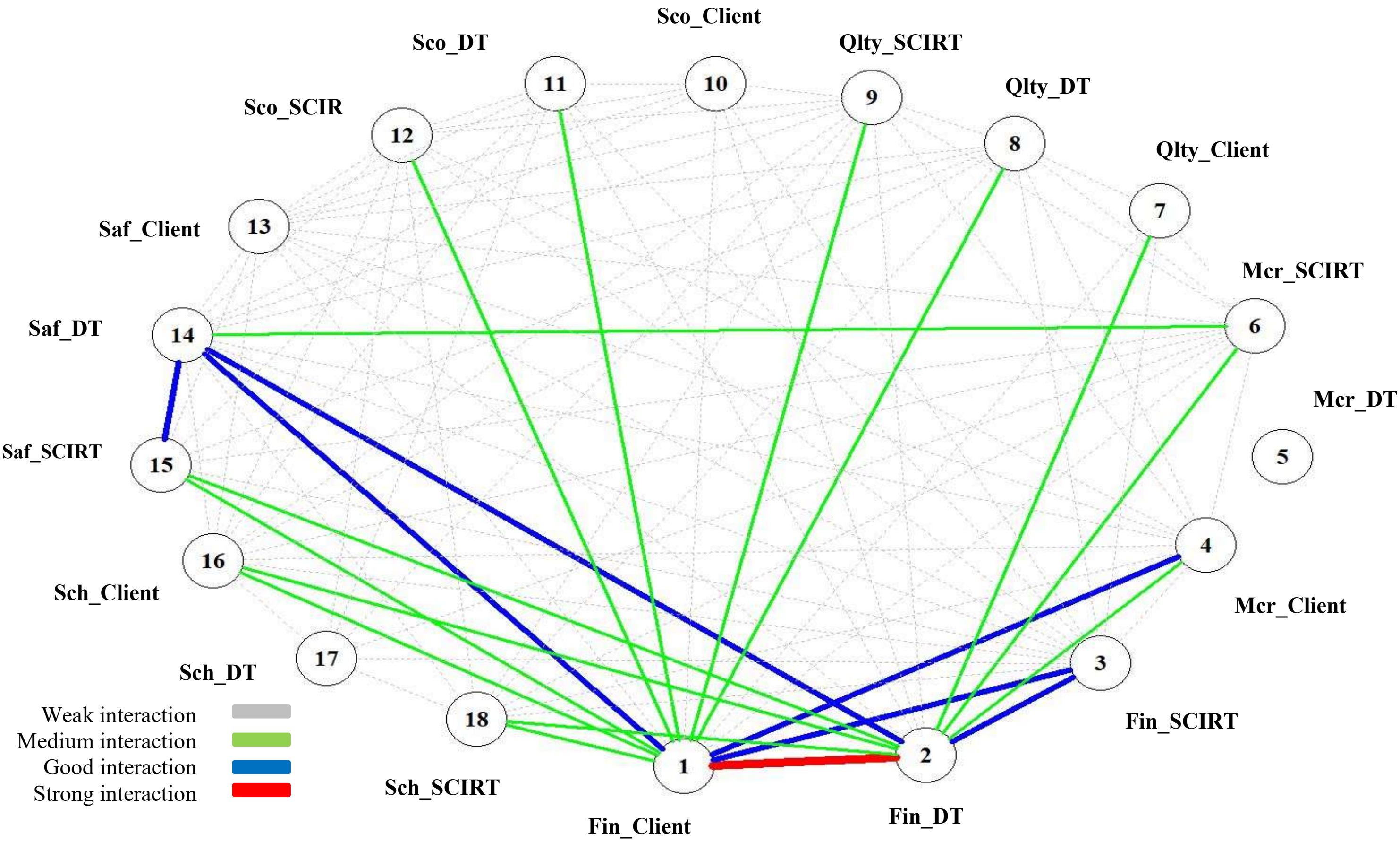


Figure 6.4: Map of Interaction between the risk groups in SCIRT.

Most of the risk groups are connected and well differentiated by a degree of interaction. However, some risk groups arise with a higher degree of interaction. Figure 6.4 represents the map of interactions for risk groups with a level of interaction of medium and above (with a score of 2 or more) in colour, while the weak interactions are represented in grey.

For a better understanding of the key risk groups that impact the system in post-disaster situations and to identify the interaction between the risk groups, a separate chart for the high-interaction risk groups, with a score of 3 and above, is provided below (Figure 6.5). The numbers beside the risk groups are the risk groups' IDs from the combined impact matrix Table 6.5.

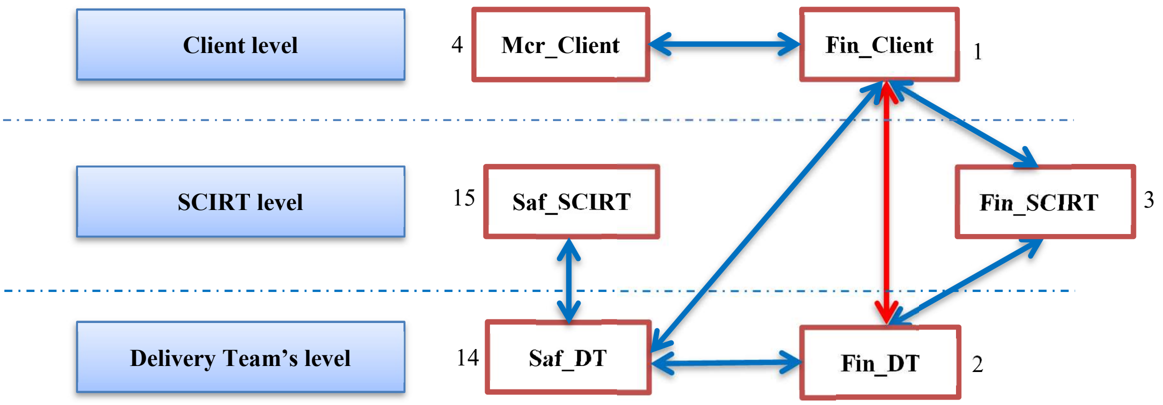


Figure 6.5: Key risk groups with good and strong levels of interactions inside SCIRT.

Financial risk groups are highlighted in red for both client and delivery-team levels (see the connection between 1&2) represent the highest influence in the programme and the highest interaction between them. This shows how both the client and delivery teams gave financial risk and value for money, which was the highest priority in post-disaster. Primarily, this was to secure the post-disaster funding issues and to ensure the trust between the client and the delivery teams to deliver the projects. Based on the four participants from the interviews, (see appendix E, Header 1&8), building trust was the one of the main reasons for creating the SCIRT alliance; also, to secure enough resources to deliver the volume of work after the disaster at a fair cost and then avoid any sharp increase of prices in the market. On the other hand, it showed the macro risks are influencing the financial risks at the client level and then through to the three levels (see the connection between Mcr_Client & Fin_Client and the connection from Fin_Client to the levels below). That could be explained by the political influence inside post-disaster recovery systems at the client level.

The second highest level of interaction of risk groups in the system is highlighted in blue. One of the major influences is the financial risks for SCIRT as it is connected to both the client and delivery teams (see the connection between 3 & 2 & 1). It shows how SCIRT acted as a facilitator between financial risks for the client and the delivery teams. Moreover, the safety and environmental risks for both the SCIRT and the delivery team levels shows how leadership drives the safety attitude and performance in recovery projects.

The third level of influence in the system is highlighted in green. For a better understanding of the connection, Figure 6.6 separately shows the risk groups with a medium degree of connection and influence in the recovery system. As can be seen, the financial risk groups for both client and delivery teams, are connected to most of the other risk groups like schedule, quality, scope, safety and environment. All management levels are indicating the vital importance of the financial risks in recovery projects.

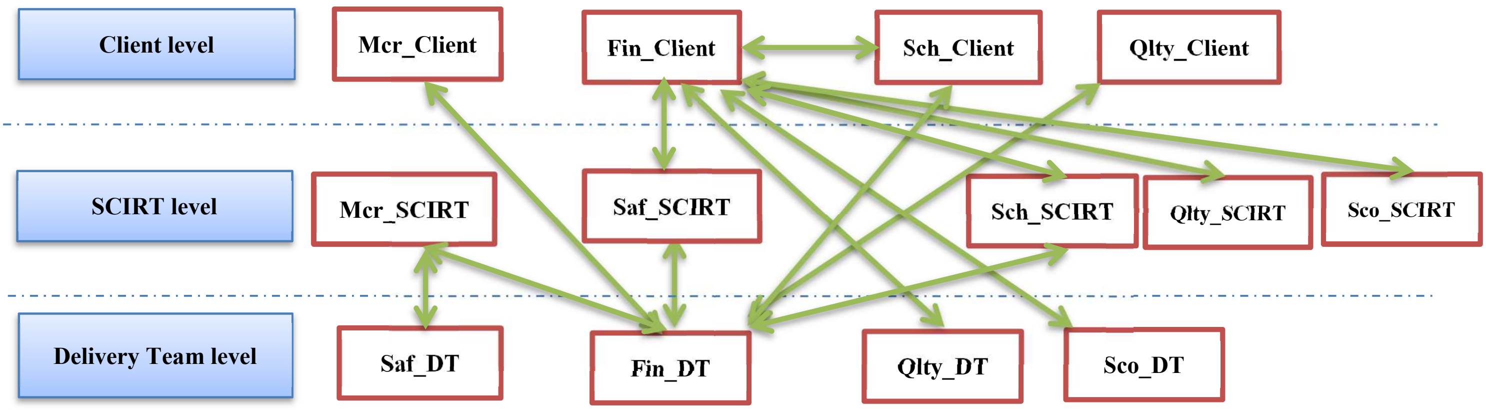


Figure 6.6: Key risk groups with medium influence rank inside SCIRT.

Moreover, it is also driven by macro risk groups for both client and SCIRT. The importance of quality risks for all management levels can also not be ignored. This is because of the lack of human resources and inexperience are common reasons for failure due to the uniqueness of the situation and the post-disaster movement of the workforce. Nevertheless, the scope of the risk groups for both SCIRT and the delivery teams has been defined as a crucial influence risk group. The reason behind that has been confirmed by five participants in the interviews (Appendix E, Header 17). The uncertainty of scope in the recovery projects is a big challenge, especially for underground conditions. Some of the projects have not been appropriately defined because of urgency and lack of time. On the contrary, macro risks for delivery teams were not considered as key risks. Participants believed that the influence of politicians on the operation and delivery was not making much of a difference, as companies will deliver any project as long as it is adequately funded.

6.3 Summary

This chapter investigated the influence of risk groups inside recovery systems between the different management layers to form a picture of the dynamics of risk management in recovery projects. It has been found, that even with the high level of emotional involvement after a disaster, and the humanity and environmental crisis, the financial risks for both the client and delivery teams have been the main concerns and drivers. The map of interactions showed that financial risks for clients and delivery teams were the most well-connected risk groups to most of the other risk groups in the recovery system. The reasons are that after the disaster, the client realises three things; the lack of resources risk following from the expected high volume of work, the risk of losing control over the cost, and the risks associated with the funding. This motivated the client to secure the resources for the recovery programme by creating a recovery alliance with five major construction companies in the market. Also, communicate that the funding is available to increase the trust between all parties.

The strong influence of the macro risk group, at the client level, and on the recovery risk-management dynamics, was due to the political, media and public involvement with the stakeholders. On the contrary, macro risks for delivery teams were not considered as key risks due to the contractual commitments. Finally, the strong influence of safety and environmental risks was driven by SCIRT to secure the safety of people as it was a high priority after the disaster.

Chapter 7: Critical Success Factors of Risk Management in Recovery Projects

7.1 Introduction

After analysing the critical risks and the interactions between these risks in recovery systems in the previous chapters, this chapter examines the Critical Success Factors (CSFs) for risk management's best practices in recovery projects by using SCIRT as a case study. As it has been mentioned in the literature review (Chapter 2), Botha & Scheepbouwer, (2014) explored the risk management inside SCIRT through two phases, the Ramp-up phase and the Steady State phase. Between the Ramp-up phase and the Steady State phase, there was a noticeable improvement of the RMM inside SCIRT. This increase in RMM has been investigated for critical success factors by following two methods; by exploring the experience of risk-and-construction professionals, and by using the analytical method of historical projects inside the SCIRT programme. Both methods were used to combine the benefits of both expert knowledge and historical evidence (Figure 7.1). Exploring the professional experience has targeted the participant's opinion about CSFs, and the analytical method was used to investigate the factors that influence RMM in the recovery system.

The data collection included a combination of surveys and interviews and historical data of 100 projects from the SCIRT programme. The survey and interviews are the same ones that have been used from the start of the research (Table 3.1). However, there were dedicated sections in the survey and the main interviews to cover this chapter. QCA was used to investigate the correlation between different performance indicators and the RMM of recovery projects inside SCIRT. It is also important to mention that QCA explores the correlation and not the causation in this study.

7.2 The structure of this chapter

The methodology adopted both qualitative and quantitative approaches to investigate the CSFs in the recovery project. The methodology included extracting the information from the industry experts by using a survey, and in-depth semi-structured interviews, the same ones that have been used from the start of the research (Table 3.1). However, there were dedicated sections to collect the data used in this chapter. This data was combined with the analysis of recorded data of 100 recovery projects from SCIRT using QCA to investigate the relation between different Key Performance Indicators (KPIs) and RMM. Based on the information provided from SCIRT, there was no numerical KPI for risk management inside SCIRT. However, there was a clear push from management towards improving the risk management practices throughout the programme. It is obvious that a successful project should perform well in risk management since it is one of the main knowledge areas for project management (PMI, 2013). There was a reflection from the interviews to check the relationship between specific KPIs and RMM inside SCIRT and investigate which one of the KPIs correlated with improving risk management in SCIRT. Even more importantly, it could be used as a numerical indicator of the improvement of RMM inside post-disaster recovery systems. Figure 7.1 summarises the methods used to investigate CSFs in this chapter.

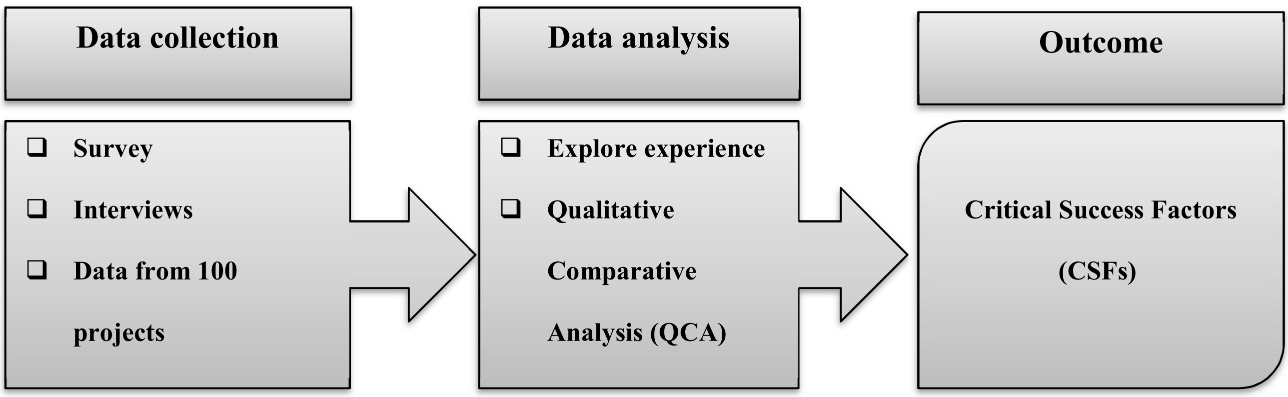


Figure 7.1: The methods to investigate the CSFs in PDRM

7.2.1 Survey and Interview Approach

The mixed quantitative and qualitative data-collection approach, based on face-to-face interviews and a survey, besides investigation of 100 project data records have been used to investigate the CSFs in recovery projects. The range of participants in this study covered project managers, estimators, quality-control experts, project controllers, designers, and asset management as per Table 3.1. The participants were asked their opinions and thoughts about the critical success factors. These factors could be used as a standard on how to improve the effectiveness of risk management practices in recovery projects and contribute to the principles of the PDRM model.

7.2.2 Qualitative Comparative Analysis

Ragin introduced QCA in 1987 as a step towards qualitative and quantitative analysis when he faced challenges over the causal inference problems generated by a small sample. QCA is capable of investigation of significant cross-case patterns with respect to the diversity of the cases and their heterogeneity. It allows comparison of cases as configurations take into consideration the different conditions and contexts. It is an effective method to capture the complex causations and facilitate a good counterfactual analysis in a complex system (Rihoux & Ragin, 2008).

The QCA analysis includes the following phases: identifying relevant cases and causal conditions, establishing the data matrix, constructing the truth-table and resolving contradictions, analysing the truth table and, finally, evaluating the results and the findings (Ragin, 2000).

Establishing the data matrix can be done using two techniques, crisp-set analysis or fuzzy-set analysis. Crisp-set analysis (set containing dichotomous values) is meant to investigate the impact of the existence of a factor to achieve a selected outcome inside a system, whereas fuzzy-set analysis is more to investigate the impact of the change of a variable to achieve a selected outcome inside a system (Vlachos & Sergiadis, 2009).

The reason for selecting the crisp-set technique over the fuzzy-set technique in this study was because the crisp-set analysis was enough to achieve the main objectives of this chapter based on the type of information available. Fuzzy set techniques would have required more technical information which was limited in this case study.

The crisp-set analysis was selected to investigate the influence of different performance indicators, such as project-cost performance into the outcome, which is the RMM. It was meant to assign a value of either 0 if absent or 1 if present to symbolise the existence of a factor in a system.

The correlation between specific KPIs inside post-disaster recovery systems was investigated using QCA of data from 100 projects which were selected randomly and were released by SCIRT. This data set comprised of the risk registers, project records and final costs of the completed projects as cases for QCA. Fifty projects from the Ramp-Up phase, representing the period where the RMM was low and fifty projects from the Steady State phase representing the period where the RMM was high. The relation between individual factors and RMM improvement in both periods would be measured.

The projects included stormwater, wastewater and roading infrastructure recovery ranging in final cost from $40,000 to $22,000,000. Any assumptions made during the analysis were verified by members of SCIRT. The results of the study were discussed with representatives from SCIRT and others in the construction industry to confirm the appropriateness of the practical interpretation of results.

7.3 Analysis

7.3.1 Survey and Interview Analysis

After conducting interviews and surveys with risk-and-construction professionals, the participants highlighted the key CSFs that should be considered when dealing with PDRM. These factors are illustrated in the following section based on the participants' opinions. More information regarding the participant's inputs and their transcripts in the main interviews are in appendix E.

7.3.1.1 Building trust between all parties

Based on the result of the survey, 95% of the participants believed that trust among the three management levels, client, alliance management, and alliance execution, is crucial in recovery projects.

Discussing this idea in the interview, participants confirmed the importance of trust and some of them mentioned that there was much trust between clients, alliance management and the alliance execution team. Participants explained how SCIRT's success was based on a team effort, and trust was the foundation of better teamwork. Table 7.1 summarises some of the participants' comments on trust in recovery systems.

Table 7.1: Interview participants' comments on trust.

Participant	***Comments***
Participant P5	Believed that trust and openness to internal and external stakeholders, the community and people are vital in recovery projects. People would like to know what is happening in their surroundings.
Participant P6	Mentioned that the trust between the top management and their crews is crucial for more effective risk management. When the people in the organisation feel like a part of the business and align with the business' values, the possibility of risk is mitigated by the staff.
Participant P21	Explained that in BAU, clients normally seek external agencies to control the quality of the contractors, but since they did not have the luxury of time in a post-disaster scenario, the client and their representatives were more into internal quality-assurance procedure from the delivery teams. Based on trust, the client gave the opportunity to the delivery teams to deliver a quality product faster to meet the deadlines.
Participant P23	Highlighted the importance of trust between the government and the private companies doing the recovery based on openness.
Participant P25	Explained how the client should build trust with the delivery teams through the right procurement model. The participant mentioned that the contract model, which was called the pain/gain model, was created to reduce the delivery teams' financial risks. The contractors will get paid for the work they do, and they may get extra profit if they do well under that model. This instantly secured the delivery team's trust in the availability of funding and reduced the risk appetite in the recovery programme. In SCIRT, due to time pressures, some of the TOCs were defined in a hurry and others were undervalued. Some delivery teams started with insufficient TOC. Trust between SCIRT and the delivery teams made them accomplish their work without any delays. The delivery teams were sure that any extra work would be compensated later based on the contractual model.

7.3.1.2 Clearer communication and structuring constant and consistent message

In post-disaster situations, 84% of the survey participants believed that regular communication between management and staff is the most important activity. On the other hand, the interviewee endorsed the importance of consistent messaging to the people, and clearer communication between teams in recovery projects as below. Table 7.2 summarised some of the participants' comments on communications.

Table 7.2: Interview participants' comments on communication.

Participant	***Comments***
Participant P4	Stated that after a disaster people would like to know what has been happening in their surroundings. Clearer communication is important when dealing with a post-disaster situation. Communication is required to assure recovery team here to make people's life easier. Also, the staff must be properly assured, through appropriate communication channels, that they will not be harmed. Lack of communication will only increase irritation.
Participant P5	Indicated that delivering one consistent message to the people is crucial in recovery projects because changing promises and messages can damage people's belief.
Participant P18	Indicated the need to have a commitment from the recovery team for effective risk management and best practices. The realistic identification of the strategic risks and the agreement to a procedure of managing these risks at a higher level was also important. One of the key risks in the delivery phase is to give the people different messages, which could lead to confusion and chaos. The participant also mentioned that SCIRT is managing the communication well and keeping the community informed about the volume of work. The SCIRT programme has been one of the best practices of good communication and lessons learned. Because of the competitive market, in BAU, there was no communication of risks associated with a disaster.

7.3.1.3 Establishing a more stable working environment after a disaster

One of the highest ratings was given to a more stable environment with fewer changes. Eighty-five percent of participants in the survey believed that high employee turnover is likely to happen in recovery projects. Nevertheless, participants P1 and P6 illustrated that due to the transient nature of the work where people are only employed on a temporary basis, the motivational levels could be lower than normal, resulting in a negative impact on understanding and treatment of risk. This problem is compounded when staff turnover is high due to skill shortages and external influences and demands from workload elsewhere. Interview participants had highlighted the same risk. Table 7.3 summarises some of the participants' comments on the working environment after a disaster.

Table 7.3: Participants' comments on the working environment after a disaster.

Participant	***Comments***
Participant P5	Explained it is more complicated after a disaster regarding the resources. Work needs to be delivered by staff who are under pressure, A successful recovery-project manager needs to ease that pressure and find ways to make it easier for everyone.
Participant P10	Mentioned that it is important to observe the people and check their needs to get what is expected from them in this new working environment.
Participant P13	Mentioned that staff retention could give rise to a high risk inside the recovery programme. Although a significant amount of time and effort is invested in staff training, they will keep seeking better opportunities causing improvement in staff retention.
Participant P23	Explained that the well-being of staff, a secure and more stable working environment would maintain better risk management in recovery projects. The stable working environment is affecting the risk management and the overall performance of the project because inexperienced staff need more time and training to be familiar with the projects, the new culture and procedures. This increases the likelihood of risks all over the programme.

7.3.1.4 Competence and clear allocation of risk management responsibilities.

Seventy-three percent of the survey participants revealed that clear allocation of risk management responsibilities is the most important step from the top management to support the risk management policy in recovery projects.

The interviewees supported the importance of allocating risk management staff and their responsibilities and competence in recovery projects. Table 7.4 summarises some of the participants' comments on competence.

Table 7.4: Interview participants' comments on competence.

Participant	***Comments***
Participant P2	Clarified that the project manager needs to be involved, take responsibility for the risks, and be ready for the outcome.
Participant P6	Mentioned the importance of skilled resources. It is not only about doing the role; it is more about competently doing it. It is an important factor, which must be taken into consideration to avoid risk.
Participant P10	Explained that the biggest issue recovery organisations have after earthquakes, is that there is a lot of work around that will increase as they proceed. Hence, the recovery organisations hire new staff and allocate more and newer resources, increasing the risk that some staff are incompetent.
Participant P24	Explained it is important to use competent contractors that are self-managed and could save time and money in recovery projects.

7.3.1.5 Risk management culture shift after disaster.

More than 60% of the participants believed that helping establish and embed the risk management culture inside the recovery organisations and promoting risk awareness, is a crucial activity that top management should perform in recovery projects. Participant P6 mentioned that due to a general skill shortage, it is difficult to develop a risk-aware culture and attitude. Table 7.5 summarises the participants' comments on culture.

Table 7.5: Interview participants' comments on culture.

Participant	***Comments***
Participant P1	Explained the importance of focusing on the safety culture in recovery projects.
Participant P2	Highlighted the importance of having clear common culture driven by post-disaster recovery system to achieve the desired goals. Also, there is a need for flexibility and change management to shift the culture in the right direction.
Participant P3	Stated there were many foreigners working in the recovery programme, and they brought their own culture, which created a mixed culture.
Participant P5	Mentioned that culture is critical in recovery projects in both ways: organisational and public culture.
Participant P6	Stated that if the culture is right, there is a trust between people in the management tier, everyone feels a part of the business, and they are aligned with the business values, which would improve the overall risk management awareness inside PDR.
Participant P9	Stated that risk management in post-disaster depends on the organisation culture, which needs to be open for changes and flexible to overcome the communication barriers.
Participant 11	Indicated that the culture had to change from a business mindset to include the human dimension, and the community was needing a bit of a culture shift from day one.
Participant P13	Mentioned the link between the company culture and the performance inside the business. Some of the staff and team's cultures are stronger than others which has impacted both negatively and positively on the overall performance of the recovery programme.
Participant 19	Mentioned that the culture drives the attitude towards risks; therefore, it is important that the leadership give enough attention to the cultural shift.

7.3.1.6 Critical thinking and prioritisation in all levels risks, resources, and work.

One of the key success factors of more effective risk management in recovery projects that have been identified by several interviewees is critical thinking and risk prioritisation due to the time constraints and the emergency type of projects involved in the programme. Some risks are more critical than other risks, such as the safety of people, especially at the beginning of the recovery programme. Table 7.6 summarises some of the participants' comments on risk prioritisation.

Table 7.6: Interview participants' comments on risk prioritisation.

Participant	***Comments***
Participant P1	Mentioned that both risk and resources prioritisations are important parts of risk management in the recovery project.
Participant P5	Mentioned that Prioritisation for risk management inside recovery projects is crucial due to the chaos of the disaster and emergency procedures. In addition, the management team should review the Prioritisation list frequently and keep it alive and active, as it is always different throughout the programme.
Participant P7	Explained that at the beginning of the SCIRT programme, the top priority was to provide the essentials needed to keep life going, such as clean water. Hence, the right thing to do in recovery projects is to prioritise.
Participant P10	Mentioned critical thinking as an important part of the PDRM processes including risk assessment and risk treatment.
Participant P13	Stated that risk management was always present in construction but in the last number of years, it became more important, however, critical thinking is required in recovery projects because of the complexity which should be broken down by the critical thinking and cooperation.
Participant P19	Credited risk prioritisation for the effectiveness of risk management in recovery projects. Prioritisation here meant acting towards the most critical risks first, for instance, fast actions towards the safety of people risks.
Participant 21	Illustrated the importance of having a priority list in such disasters to ease faster decision-making.

Participant	*Comments*
Participant 26	Explained that the prioritisation of risks is the main challenge in recovery projects, and if it is done correctly, it could make a huge difference regarding risk management and getting on top of the programme's critical risks. Also, mentioned that the risks are different in recovery projects as they could be related to other unforeseen threats and which is adding to the complexity of risks. Therefore, it needs critical thinking from people to identify and manage these risks.

7.3.1.7 Up-skilling up and training.

Due to the unique situation after the disaster where it could have been the first time most of the team and workforce had ever had to deal with recovery projects on such a scale, it was a critical point, which has been highlighted by several participants as a need to train and skill up the staff. Table 7.7 summarises some of the participants' comments on up-skilling staff and training.

Table 7.7: Interview participants' comments on training.

Participant	*Comments*
Participant 6	Declared that even though there was not enough time for training in recovery projects, it was important to train staff with even newer materials to avoid the risk of rework or poor quality.
Participant 10	Mentioned that lots of reworking happened due to not enough training and skilling up, as the staff did not have enough experience which increased the level of risks in the programme.
Participant 11	Stated that while looking through the risk identification inside SCIRT, the programme, risks had been identified better than the project risks. The reason behind that is the experience factor; the people who looked at the programme risks had a lot of experience. However, with the project risks, there was less experienced staff due to lack of resources after the disaster compared with the huge volume of work to be done.

Participant	*Comments*
Participant 17	Said that top management should give more training and technical support to the workforce in recovery projects to avoid reworking.
Participant 24	Mentioned that risk management in recovery projects, especially in the delivery teams, should have been driven by a considerable amount of upskilling and training.

7.3.1.8 Intelligent Risk Management Information Systems and Procedures (IRMISP)

After analysis of the interview participants' inputs, several recommendations highlighted the importance of using intelligent information systems and using the technology available for better risk management. Systems that are convenient should be used onsite to report risks directly and update the risk register, such as using applications in smart devices to update risk register. In addition, a system that is scalable is needed in order to be able to contain a large amount of information produced from the 100 projects that are all working at the same time. Systems that record the risks from older recovery projects and allow for lessons to be learned and give a feedback loop for the treatment of future projects needed to be considered for more effective PDRM. Table 7.8 summarises some of the participants' comments on technology solutions.

Table 7.8: Interview participants' comments on intelligent systems.

Participant's ID	**Comments**
Participant P18	Recommended a specific risk management system for KPI and inputs focus more on risk variables.
Participant P19	Explained that post-disaster recovery systems need to know the quantum of the faced risks and that needs intelligent integrated systems. It is important to find technical solutions from the beginning of the recovery programme, to firmly establish risk management systems and procedures that can gear up to accelerate faster than BAU to be able to face the scaling problem and the dynamic style of risks in recovery projects.

Participant's ID	**Comments**
Participant P20	Recommended the use of intelligent information systems to help in overseeing early warning measures of what is happening over time and seeing the trends in the recovery programme such as cost, and time overrun.
Participant P26	Highlighted that the strategy of the leadership in post-disaster recovery systems should support innovations, endorse the teamwork styles and the use of smart systems.

7.3.1.9 Emotional intelligence

Several participants, as detailed below, highlighted the changes in people's behaviours and the emotional involvement of most stakeholders in post-disaster recovery systems, including public and staff, which emphasised the need to have a professional team with "emotional intelligence" background to deal with and train the staff to deal with such situations. Table 7.9 summarised some of the participants' comments on emotions in recovery systems.

Table 7.9: Interview participants' comments on emotional intelligence requirement.

Participant's ID	**Comments**
Participant P1	Explained that the sense of panic in these situations makes people behave in a slightly irrational way which has required attention, especially with aftershocks.
Participant P4	Stated that communication channels with the public needed to take into consideration the emotional pressure of the people because they went through a lot. The message needed to be clear that recovery teams were here to help.
Participant P5	Mentioned the importance of finding innovative ways to address the emotional and media layers of conflict with stakeholders in post-disaster recovery systems. Innovations ways of communications to ease the pressure and be fast and accurate. Also, address the people able to work under

	emotional stress. After a disaster, the community is very different, broken, damage, panic, lack of money, people lost their jobs, etc., lots of emotion going on.
Participant P11	Said that culture within the stakeholders needs to be a proactive culture as the emotions play a bigger part in post-disaster recovery systems than BAU.
Participant P25	Mentioned that people's mental health and emotional involvement due to the high stresses after a disaster should be considered.

7.3.1.10 Effective leadership to promote innovation and motivation

Good risk management leadership and decision-making has been an effective driver in the recovery projects based on the inputs from the interview participants. Table 7.10 summarises some of the participants' comments on risk management leadership.

Table 7.10: Interview participants' comments on leadership.

Participant's ID	**Comments**
Participant P13	Explained that the complex situation in recovery projects needed to be broken down by good leaders' brain powers.
Participant P20	Explained that using professional institutions to support the leaders with knowledge is the right way to add to the risk management leadership in recovery projects.
Participant P23	Highlighted the importance of the leadership to change and drive the culture of effective risk management inside post-disaster recovery systems.
Participant P26	Mentioned that the key to success in post-disaster recovery systems is good leadership and management towards teamwork to achieve the desired successful outcome by supporting the innovation and allocate the activities to the right persons.

7.3.2 Qualitative Comparative Analysis

To clarify the evolution of risk management practices at SCIRT from the Ramp Up phase to the Steady State phase (Botha and Scheepbouwer 2014), which represents the increase of RMM inside SCIRT, QCA was conducted to investigate the correlation of different factors to the RMM. QCA can detect significant cross-case patterns concerning the diversity of the cases and their heterogeneity. It is an effective method to capture the complex causations in complex systems (Rihoux & Ragin, 2008).

The QCA factors were defined based on the available information from SCIRT of 50 projects from the Ramp Up phase and 50 projects from the Steady State phase. These factors are the Cost Performance Index (CPI), the number of Work Scope Changes (WSCs), the number of Incident Reports (IR), the number of Non-Conformity Reports (NCRs), and the Schedule Performance Index (SPI).

SCIRT used some of Earned Value Management (EVM) features, SPI and CPI, to measure the performance of the projects inside the programme. The calculation of EVM includes three main elements, Planned Value (PV), Actual Cost (AC) and Earned Value (EV). PV could be described as the approval of work to be achieved by a certain time, while AC is the cost incurred to complete the job at the same time, and EV is the value of work performed, measured by the approved budget (Erik & Antvik, 2009).

In the SCIRT programme, SPI is used as a KPI to designate how efficiently the project is progressing compared to the planned schedule and has been determined by dividing the earned value by the planned value. If SPI is equal to or greater than one, this means the project will be completed on time or ahead of schedule respectively. If SPI is less than one, this means the project is behind schedule. CPI is a KPI to measure the cost efficiency of the project and is expressed as a ratio of the earned value to the actual cost. If CPI is equal to or greater than one, this means the project spending was as planned, or the project was under budget respectively. If CPI is less than one, it means that the project is over budget (Warburton, 2010). The number of IRs and NCRs represent how the project would comply and perform in safety and quality, respectively. The correlation of these factors with the RMM in post-disaster recovery systems was analysed using fs/QCA software (Ragin & Davey, 2014). Figure 7.2 summaries the QCA used in this study.

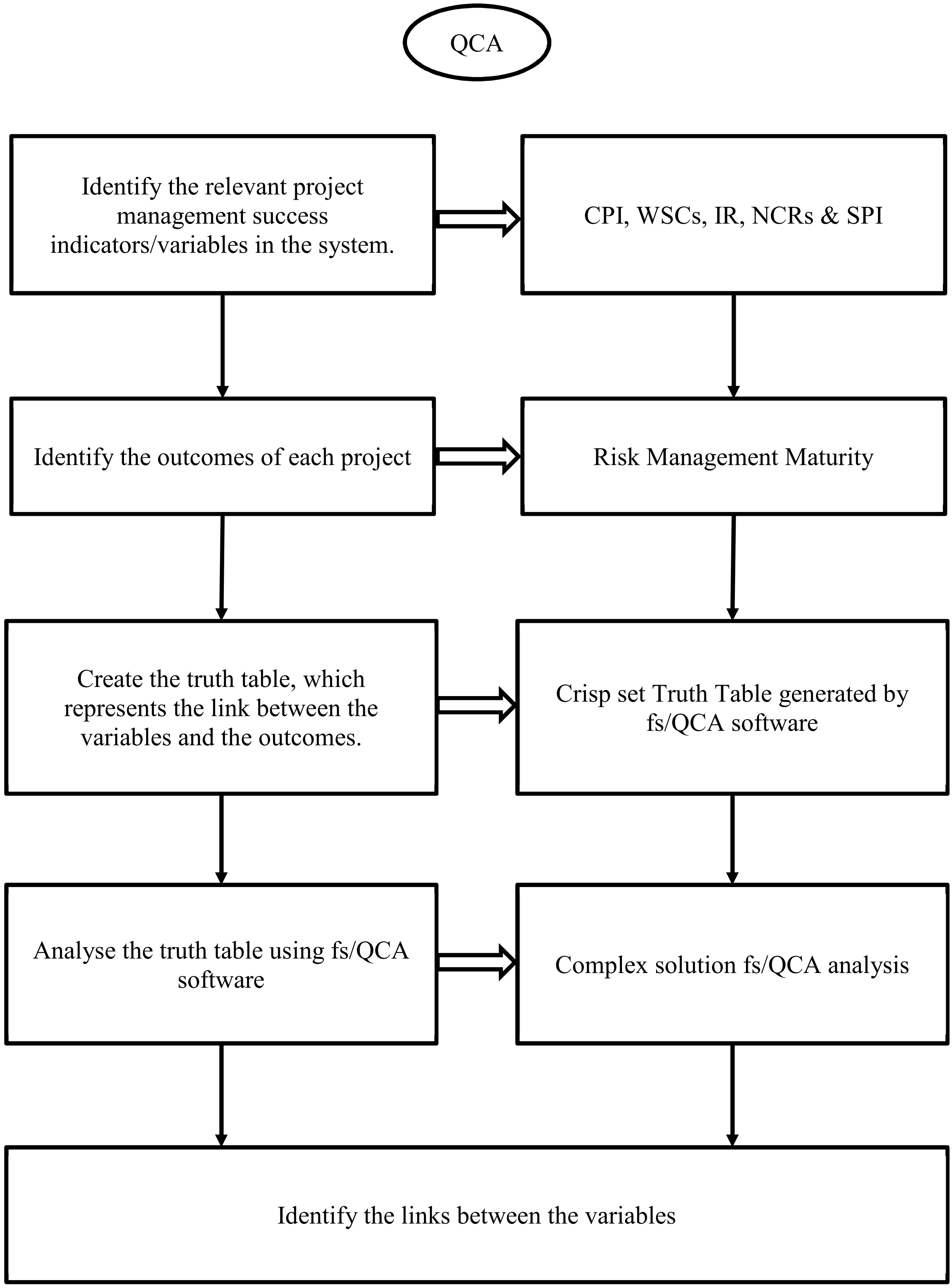


Figure 7.2: QCA in this research.

The data from the projects has been calibrated. The calibration of the data, to be ready for use in fs/QCA software, involved establishing a set of the membership's values for the outcome and conversion thresholds. Based on the crisp-set analysis, each case is assigned a score for each factor and outcome; 1 (yes/present) or 0 (no/absent). Here, (1) was assigned to the positive performance and (0) for the negative performance. Appendix G shows the Crisp-set matrix used in the calculations.

During recoding the factors, the following set membership scores were used:

- For projects in the Steady State phase the score is 1 and for the Ramp Up phase (RMM), the score is 0
- For CPI => 1 and for CPI < 1, the score is 0
- (1) for SPI => 1 and for SPI < 1, the score is 0
- (1) for NO WSCs and for projects with WSCs, the score is 0
- (1) for NO IRs and for projects with IRs, the score is 0
- (1) for NO NCRs and for projects with NCRs, the score is 0

By entering all the Crisp-data-matrix (Table 7.8 before) in fs/QCA software, the truth table can be generated (Table 7.9 before). fs/QCA software uses an algorithm to compare rows of Crisp-data-matrix to identify matching pairs combined it to the truth table. Then, fs/QCA produces a list of causal combinations linked to the outcome (Ragin, 2010). Table 7.12 represents the truth table generated by fs/QCA software based on the condition below;

- Delete rows with number of cases less than 1 and set RMM to 1 for rows with consist >= 0.8

This coding condition was used to consider the highest coverage and consistency between the cases that are over 0.8 (Figure 7.3). The condition means any rows with a consistency score of 0.8 and above will be rounded up to be a score of one. In this study, a score of 0.8 is considered to be a strong consistency score following similar previous studies. Also, it is a default feature in fs/QCA software.

Table 7.12: The Crisp-set Truth Table of the 100 projects.

RMM	SPI	WSCs	IR	NCRs	CPI	number	Raw consistency
1	1	0	1	1	1	5	1
1	1	1	1	1	1	5	1
1	0	1	1	1	0	3	1
1	0	1	0	1	1	3	1
1	1	0	0	0	0	1	1
1	1	1	1	0	1	1	1
1	1	0	0	1	1	1	1
1	1	1	0	1	1	1	1
0	0	0	1	1	1	4	0.75
0	0	1	0	0	1	6	0.67
0	1	0	0	0	1	3	0.67
0	0	0	1	0	1	3	0.67
0	0	0	0	1	1	3	0.67
0	0	0	0	1	0	2	0.5
0	1	0	0	1	0	2	0.5
0	1	0	1	1	0	2	0.5
0	1	0	1	0	1	2	0.5
0	0	0	0	0	1	21	0.38
0	0	0	0	0	0	24	0.21
0	0	0	1	0	0	4	0
0	1	0	1	0	0	2	0
0	0	0	1	1	0	1	0
0	1	1	0	0	1	1	0

In QCA, consistency refers to the percentage of causal configurations which result in the same outcome of similar composition; while coverage refers to the number of cases for which a configuration is valid (Ragin, 2010).

The raw consistency in the truth table is an indication of how steady the factors were on the same row as a subset of the outcome.

For the QCA analysis of the 100 projects' "cases", fs/QCA software was used to compute three different types of analysis, the complex, the parsimonious, and the intermediate solutions.

The basic Boolean function symbols are (+) for logical OR, (*) for logical AND, the "NOT" value represented by a [~] symbol and the arrow [→] is used to express the link between a set of conditions.

For example:

A+B *~C→ D (where D is the outcome)

This equation means A or B and not C, are correlated drivers to get D as an outcome.

Figure 7.4 represents the truth-table analysis outcome from the fs/QCA 3.0 software, which includes the three solutions.

The complex solution is the solution based on the raw data entered without any assumptions in the analysis.

The intermediate solution is a complex solution with selected assumptions used to simplify the analysis and reduce the complexity. For example, putting a condition that CPI should always be present in the calculations.

The parsimonious solution is where the software automatically reduces the relations between the factors to the smallest number of conditions possible.

In this study, the complex solution was chosen to avoid any external influence because, in both the parsimonious and intermediate solutions, a reminder or a lead can be used to simplify the calculations, which are hard to justify (Ragin, 2010). Figure 7.4 represents the truth-table analysis as an outcome from fs/QCA. In this figure, you may notice that the complex solution is the same as the intermediate solution, which is logical because no assumptions or conditions were added to the calculations.

```
**********************
*TRUTH TABLE ANALYSIS*
**********************

File:  C:/Users/Ashi/OneDrive - University of Canterbury/PhD/Qualitative comparative analysis/
software/fsQCA/fsqca30/risk awarness to cost overrun .csv
Model: RM = f(SPI, WSCs, IR, NCRs, CPI)
Algorithm: Quine-McCluskey

--- COMPLEX SOLUTION ---
frequency cutoff: 1
consistency cutoff: 1
                              raw       unique
                            coverage    coverage   consistency
                           ----------  ----------  ----------
SPI*NCRs*CPI               0.24        0.12        1
WSCs*~IR*NCRs*CPI          0.08        0.06        1
SPI*WSCs*IR*CPI            0.12        0.02        1
SPI*~WSCs*~IR*~NCRs*~CPI   0.02        0.02        1
~SPI*WSCs*IR*NCRs*~CPI     0.06        0.06        1
solution coverage: 0.4
solution consistency: 1


**********************
*TRUTH TABLE ANALYSIS*
**********************

File:  C:/Users/Ashi/OneDrive - University of Canterbury/PhD/Qualitative comparative analysis/
software/fsQCA/fsqca30/risk awarness to cost overrun .csv
Model: RM = f(SPI, WSCs, IR, NCRs, CPI)
Algorithm: Quine-McCluskey

--- PARSIMONIOUS SOLUTION ---
frequency cutoff: 1
consistency cutoff: 1
                          raw       unique
                        coverage    coverage   consistency
                       ----------  ----------  ----------
WSCs*IR                0.18        0.02        1
WSCs*NCRs              0.24        0.06        1
SPI*NCRs*CPI           0.24        0.12        1
SPI*~IR*~NCRs*~CPI     0.02        0.02        1
solution coverage: 0.4
solution consistency: 1


**********************
*TRUTH TABLE ANALYSIS*
**********************

File:  C:/Users/Ashi/OneDrive - University of Canterbury/PhD/Qualitative comparative analysis/
software/fsQCA/fsqca30/risk awarness to cost overrun .csv
Model: RM = f(SPI, WSCs, IR, NCRs, CPI)
Algorithm: Quine-McCluskey

--- INTERMEDIATE SOLUTION ---
frequency cutoff: 1
consistency cutoff: 1
Assumptions:
                              raw       unique
                            coverage    coverage   consistency
                           ----------  ----------  ----------
SPI*NCRs*CPI               0.24        0.12        1
WSCs*~IR*NCRs*CPI          0.08        0.06        1
SPI*WSCs*IR*CPI            0.12        0.02        1
SPI*~WSCs*~IR*~NCRs*~CPI   0.02        0.02        1
~SPI*WSCs*IR*NCRs*~CPI     0.06        0.06        1
solution coverage: 0.4
solution consistency: 1
```

Figure 7.4: Truth-table analysis from fs/QCA 3.0 software.

Table 7.13 shows the complex solution. According to the solution, there are five pathways. However, there are three main pathways with higher raw coverage. The pathways are represented below:

Table 7.13: Complex solution fs/QCA analysis

	Raw Coverage	**Unique Coverage**	**consistency**
SPI*NCRs*CPI	0.24	0.12	1
SPI*WSCs*IR*CPI	0.12	0.02	1
WSCs*~IR*NCRs*CPI	0.08	0.06	1
~SPI*WSCs*IR*NCRs*~CPI	0.06	0.06	1
SPI*~WSCs*~IR*~NCRs*~CPI	0.02	0.02	1
solution coverage	**0.4**		
solution consistency	**1**		

In Table 7.10, the raw-coverage column represents to what extent the pathway explains the outcome, and the unique-coverage column represents the proportion of the projects that can be explained exclusively by that pathway, while the consistency column is an indication of how steady the pathway is as a subset of the outcome.

The pathway with the highest coverage is SPI*NCRs*CPI. The pathway indicates that the improvement in RMM inside recovery organisations is an equation of high schedule performance, high safety performance, and high-cost performance. This is consistent at 1.00 and the highest raw coverage of 0.24 among the other pathways with unique coverage of 0.12.

The second pathway, SPI*WSCs*IR*CPI, indicates that better RMM inside recovery organisations is linked to a better schedule-performance index, better scope definition represented by No WSCs, better safety and better cost control. This pathway is also consistent at 1 and has a raw coverage of 0.12, but a unique coverage of 0.02, which is so low, so that this path may be ignored.

The third pathway, WSCs*~IR*NCRs*CPI, indicates that with no work, the scope changes. This indicates a more explicit scope, absence of nonconformity reports and good cost performance. Even with the existence of some incident reporting, the projects still have better RMM. This pathway is also consistent at 1 and has low raw coverage of 0.08 and low unique coverage of 0.06. This pathway was also ignored because of the low unique coverage.

Overall, the solution has a high consistency of 1 with a relatively fair coverage of 0.4. Nevertheless, the factors SPI, NCRs, CPI, WSCs existed in three pathways out of five, which indicates that there is a correlation between these factors and the improvement in RMM in the recovery programme.

On the other hand, Table 7.14 summarises data recorded from the 100 projects. The table shows 50 projects from the Ramp Up phase with a "high level of RMM" and 50 projects from the Steady State phase with a "low level of RMM", and the numbers of the projects that achieved each of the factors. It appears that all the factors improved with the improvement of the RMM inside SCIRT with different trends.

Table 7.14: Summary of the projects' data in both phases

level of RMM	***No of projects***	**NCRs**		**CPI**		**WSCs**		**SPI**		**IR**	
		No of projects	%	No of projects	%	No of projects	%	No of projects	%	No of projects	%
High	50	26	52%	38	76%	17	34%	19	38%	21	42%
Low	50	6	12%	21	42%	3	6%	7	14%	11	22%
Variance		20	40%	17	34%	14	28%	12	24%	10	20%

The variance of the percentage of the improvement between both phases for each factor was calculated and captured in Figure 7.5.

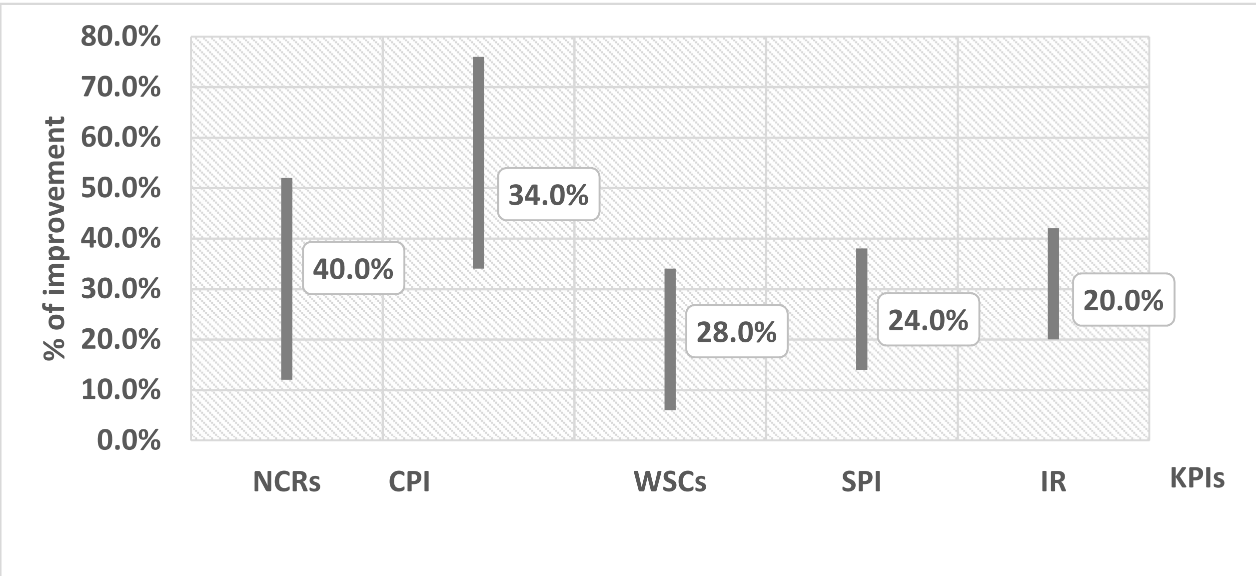


Figure 7.5: The improvement trend of the factors between the Ramp Up and Steady State phases.

Figure 7.5 shows that NCRs carried the highest variance of improvement with 40%, followed by CPI with 34%, then WSCs with 28%, then SPI with 24%, and lastly IR with 20%. This sequence gives an indication of how the factors were impacted by the improvement of RMM inside SCIRT. This endorses the importance of having effective risk management to improve the projects' performance in the recovery systems.

7.4 Summary

In this chapter, CSFs of risk management in recovery projects have been investigated using SCIRT as a case study. The methodology of these investigations was based on a survey and interviews with risk professionals inside SCIRT, and QCA of one hundred recovery projects.

Crisp set analysis of QCA was used to represent the links between the different performance indicators and RMM in recovery projects. After the analysis of the survey and the interviews, the study found several crucial factors that should be taken into consideration in recovery projects. These factors contributed to shaping the PDRM-model's principles, as will be seen in Chapter 8. These factors are building trust between all parties; clearer communication and consistent messaging; establishing a more stable working environment; competence and a clear allocation of risk management responsibilities; post-disaster risk management cultural shift; risk prioritisation and up-skilling and training the staff.

On the other side, this chapter has advanced the unexploited potential of fsQCA in utilising cases of risk management in a theoretically informed way. In particular, this study used a crisp set of QCA to represent the links between the different performance indicators and RMM in recovery projects. QCA demonstrated the effective contribution and the positive correlation of high CPI, SPI, NCR into RMM in recovery projects. Nevertheless, there is a positive influence of a smaller number of WSC, and a lower number of IR to improve the risk management performance in recovery projects.

It appears that better overall performance of a construction project is associated with the improvement of the RMM inside the recovery systems, which was supported by statistical and qualitative data analysis of over 100 projects. This should encourage construction practitioners to support proactive risk management and RMM as a precursor to more effective recovery project delivery.

The discussion and the investigations in this chapter can provide some guidance for QCA researchers on how to approach fs/QCA for more investigations in risk management using the crisp set.

Chapter 8: Post-Disaster Risk Management Model Development

8.1 Introduction

In this chapter, the PDRM model will be developed. System Dynamics (SD) modelling based on a Grounded Theory Approach (GTA) will be used to look in detail at the concepts, and the attributes that influence risk management in recovery projects and then the PDRM model will be visualised with CLD.

Previous chapters describe how the critical risks have been identified (Chapter 5) and investigating its dynamics (Chapter 6) and exploring the CSFs in the recovery systems (Chapter 7). As described in Chapter 3, SCIRT will be used as a case study to develop the PDRM model. The SCIRT alliance had been created to restore the infrastructure in Christchurch, New Zealand, after the Canterbury 2011 earthquakes, and is an example of a dynamic, complex recovery system. Therefore, SD was selected to break down and investigate this complexity based on GTA. CLD, as a tool of SD, was selected to visualise the PDRM model. Computer software has participated in the development of this model, NVivo software was used to help in the coding process, and Vensim software was used to create the CLD of the PDRM model. The PDRM model is represented as a causal loop diagram in Figure 8.46, and it contains the 10 principles and 26 concepts with their attributes. The principles serve as the foundation of the model, while the concepts refer to the essential features of the model.

8.2 The structure of this chapter

This section introduces the use of the SCIRT case study, explains the data collection stage, and describes the coding stage up to generating the CLDs and developing the PPRMM in more detail.

Interviews served as the main source of data for GTA to develop the CLD. The interviews were conducted with 20 risk and construction professionals from the SCIRT, each lasting between 30 minutes and an hour. The interviews were recorded and transcribed. This raw textual data was then used as the main input in the coding procedure. As a secondary source, the outcomes from AHP, QCA, and STMs have contributed to shaping the model's principles and concepts. It was also used to endorse and support the SD outcomes and to add another dimension of certainty. The use of these methods combined has created an integrated way of developing the final research outcome and understanding the fundamentals of risk management inside the case study.

The SD modelling in this study is divided into two stages, the coding process using NVivo 11 software, and the model development using CLD Vensim software. The coding process refers to analysing the raw data from the participants' interviews, finding the common themes and the links between these themes and visualise these themes using an SD modelling tool to understand the system. The coding process in this study is based on Eker and Zimmermann's (2016) alternative coding approach. It includes identifying concepts and discovering themes in the data (which is called "open coding"), disaggregating these concepts into variables (which is called "axial coding"), and identifying causal relationships and finally building the CLD.

Figure 8.1 provides a brief outline of the methods used in this chapter. The following stages can be identified in the methodology. The input, the Raw Data from interviews (1.1) and the outcomes from AHP, QCA and STMs (1.2), which are the critical risks, the dynamics between these risks and the CSFs. These inputs were used in the coding process and the core of the PDRM-model's principles. This allowed NVivo to be used (2.) to find the concepts/ themes hidden in the inputs. This process called "Open Coding" and worked as follows; the interviews' transcripts were uploaded into NVivo, then the data were analysed carefully, and the common themes were highlighted and categorised.

In the next step (2.2) axial coding was used to disaggregate the concepts into variables. These variables represent the children attributes under the concepts that drive risk management in recovery projects. With the variables separated, NVivo software was used to identifying causal relationships between these variables (3.1). Then, the concepts and its variables were transformed into individual CLDs using Vensim software. Finally, a combined CLD was created to represent the PDRM model (4.) using Vensim software.

Please note that Appendix E contains most of the raw data from the participants' interviews and the coding process. This chapter contains only the summarised essential information. More detailed information, including context can be found in Appendix E.

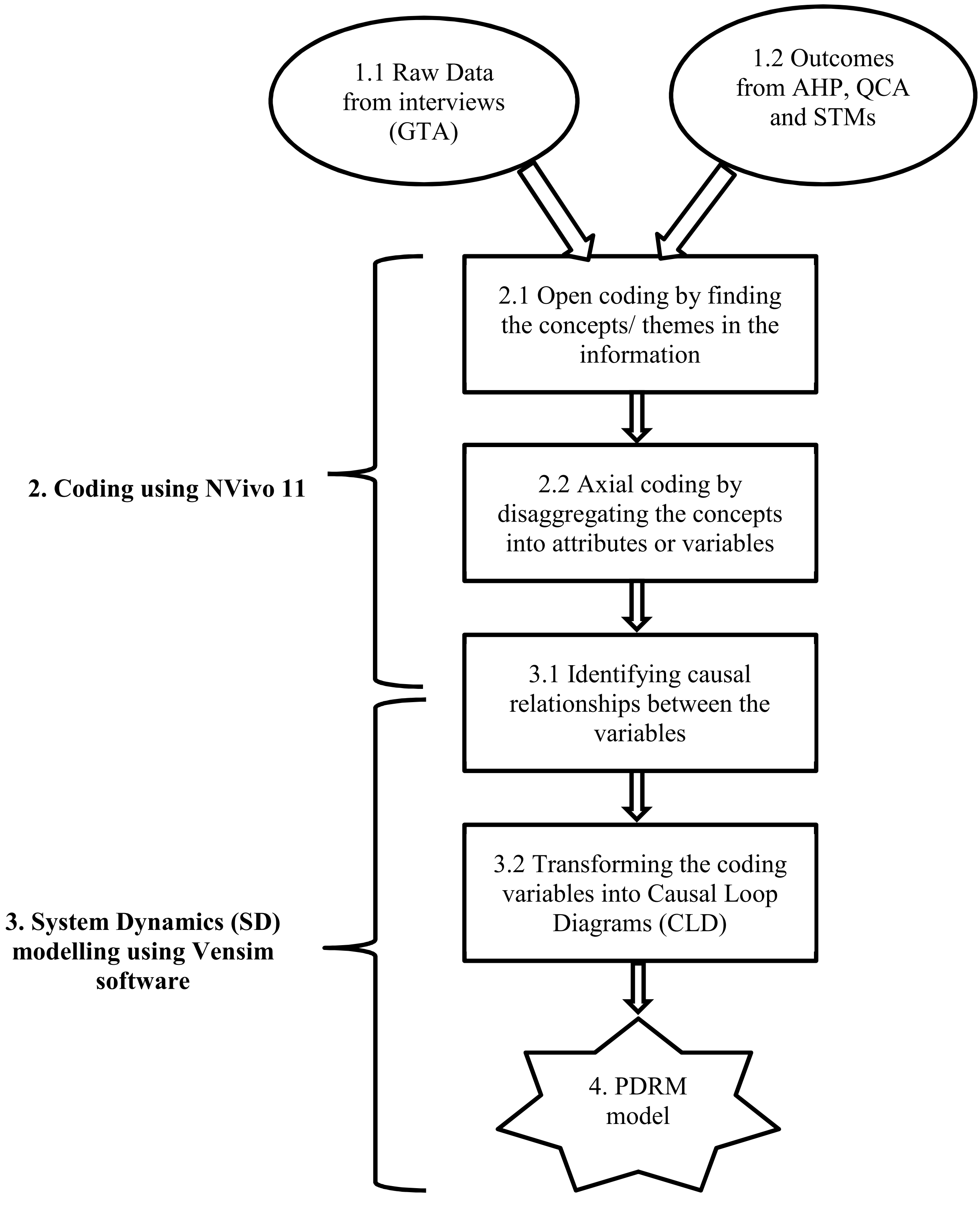


Figure 8.1: Summary of SD modelling methods used in this study.

8.2.1 Characteristics of the coding stage

Eker and Zimmermann (2016) identified three characteristics of the coding process, grouping, data collection and coder characteristics. Each one of these characteristics includes two research design dimensions, as can be seen in Figure 8.2.

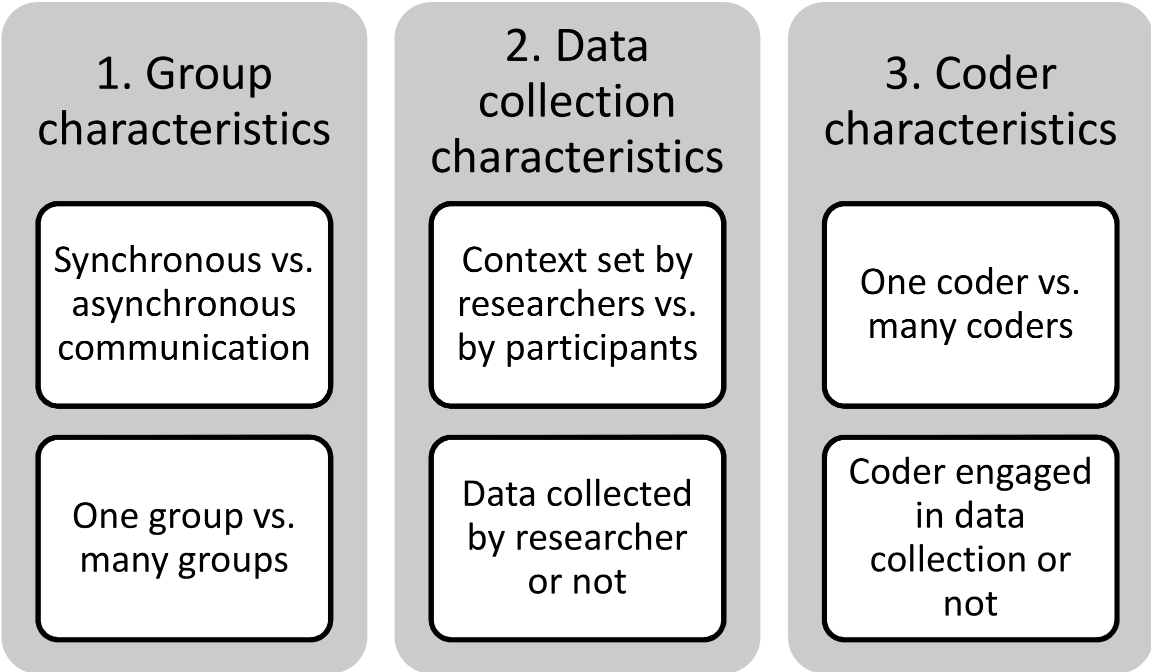


Figure 8.2: Three research design dimensions for an alternative coding process (Eker & Zimmermann, 2016).

The following section is going through these three dimensions and discusses them in present study.

1. Group characteristics, the participants were from many groups spread between the three management levels: client, SCIRT and delivery team (see Table 3.1). The communication with these groups was a mixture of synchronous and asynchronous.
    - Asynchronous is where the interviewer is not present at the same time the information has been captured, but he provides online access for information to be available at any time. Participants are free to contribute whenever they choose, which refers to this study to the online survey.
    - Synchronous is where the interviewer is present when the information has been captured, which refers in this study to the interviews and the brainstorming.

2. Data collection characteristics, each participant was interviewed individually. The development of the causal maps was based on the collective information from all the participants. The context from the interviews was based on semi-structured interview questions with a mixture of open-ended questions, and multi-choice and rating questions. This allowed the participants to express their opinion freely in the interested areas and avoid missing out the points of interest.
3. Regarding the coder characteristics, all the data collection was done by one coder, "the researcher" with direct engagement.

A summary of the research design characteristics in present study is listed in Figure 8.3

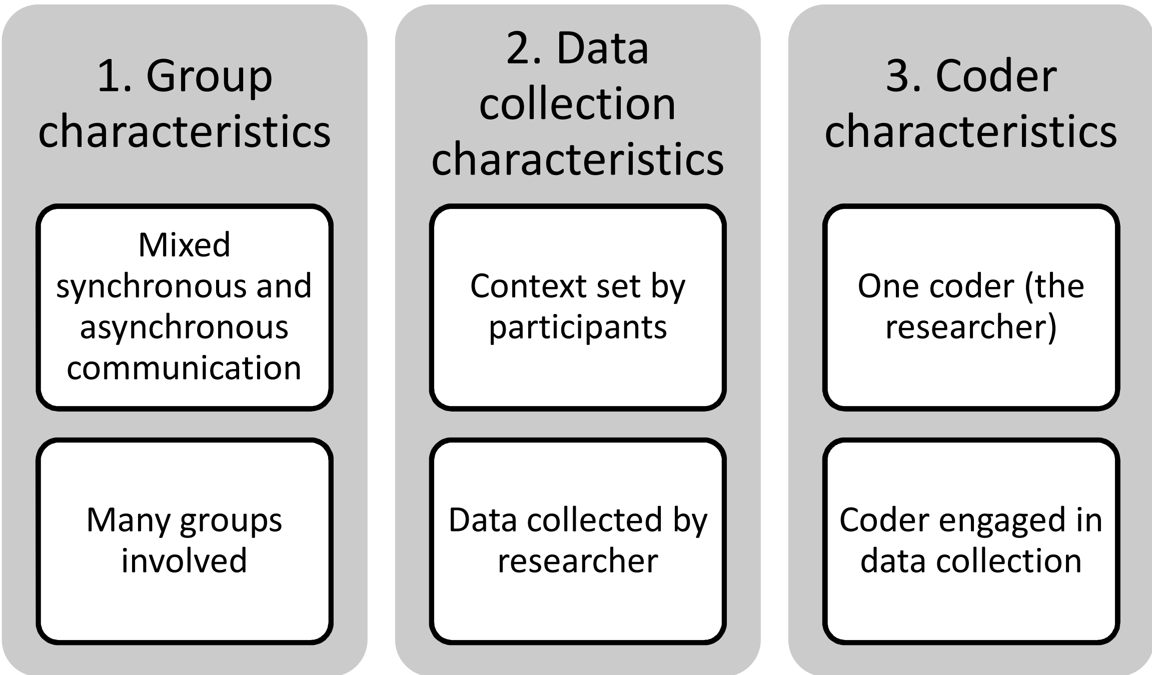


Figure 8.3: Research design characteristics for this research

NVivo version 11 software was used in the coding process in this research. It is a powerful tool for coding from various qualitative sources of data, such as interviews, into nodes, which are referred to as concepts in the research market (Bazeley & Jackson, 2013; Woolf & Silver, 2017; Phillips & Lu, 2018). These nodes then are disaggregated into variables then reorganised into a hierarchical structure; this stage is called axial coding. As NVivo was not developed to produce CLDs, a different SD modelling software called Vensim was used to produce the final model.

The coding inside NVivo was done in three rounds. The first round was the initial coding, which represented the first cut of coding from the raw data. The second round was reviewing the coding and filling the gaps, which has been done in cooperation with the research supervisor. The third round was reflecting comments in the software.

8.2.2 The Coding process in this research

In Figure 8.2, the coding process in this research contains four steps: the open coding, the axial coding, identifying causal relationships, and developing the CLD.

8.2.2.1 Step 1: Open coding

This step aimed to identify the concepts or the nodes in the raw data starting with understanding the context and producing a list of the main elements and the boundaries of the system. Some specific questions were needed in the interviews in order to capture a concept. Therefore, a semi-structured interview was favoured over an interview without structure. NVivo 11 was used to identify the different concepts.

8.2.2.2 Step 2: Axial coding

Once again, NVivo 11 was used to facilitate this step. In this step, each of the key concepts was disaggregated into child nodes with a hierarchical parent-child relationship in NVivo based on the context and the participants' inputs.

8.2.2.3 Step 3: Identify causal relationships

To find causal relationships in the transcripts, the researcher looked for words or expressions from interviewees to identify a connection between the variables such as "because", "if ... then". Also, any causal relationships between concepts could also be inferred from the answers using general understanding without specific indicator words. In Vensim, the relationships were represented by arrows. The direction of the arrow represents the (causal) direction of the influence.

8.2.2.4 Step 4: Develop the Causal Loops Diagrams (CLD)

The last step included visualising the variables influencing each concept using CLD. Vensim version 7.2 was used to develop the CLD for each concept and to develop the overall CLD of the PDRM model.

There is a hierarchical relationship between the three main components in this step; the node, the child node, and the CLD. Nodes are the first level in the hierarchy and, in this research, are the 26 concepts. The child nodes are the main variables under each concept and represent the second level in the hierarchy, and the CLD represents the third level in the hierarchy. Figure 8.4 shows the hierarchy relation between node, child node and CLD.

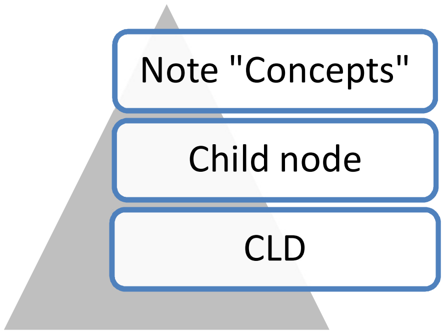


Figure 8.4: Hierarchy explains the relation between the node and the CLD.

In the CLDs, the arrows are colour coded; red with a negative symbol at the head of the arrow for negative influence and blue colour with a positive symbol at the head of the arrow for positive influence. Positive influence means the increment change in one variable increases the amount of the other variable and the other way around for negative influence. A positive influence in CLD means the variable at the tail of the arrow increasing the variable at the head of the arrow.

8.3 Results and comments

This section presents the essential outcomes from the coding process. More detailed information about the participants' inputs is available in Appendix E. The participants' inputs are identified with "Header 1 to 26". The transcripts from the participants' interviews were entered in the NVivo software and then after an in-depth examination of the context by the researcher and the use of NVivo analysis features, the open coding stage was achieved. The outcomes from the open coding stage are 26 key concepts that drive risk management inside recovery projects. Table 8.1 represents these key concepts.

Table 8.1: Concepts drive risk management in recovery projects

Concepts drive risk management in recovery projects	Establish context
	Risk assessment
	Risk treatment
	Monitoring and controlling
	Communications in recovery projects
	Resources in recovery projects
	Culture after disaster
	Trust
	Complexity levels after disaster
	Public engagement
	Different market after a disaster
	Different risk profile
	RMM in recovery projects
	Quality Control (QC) and Quality Assurance (QA)
	risk management approach “Centralised vs decentralised approach”
	Prioritisation of work and risks
	Undefined scope of work and uncertainty levels in recovery projects
	Interaction and conflicts of interest
	Processes, legal changes and consents
	Leadership and Decision making
	Disaster and project types
	Loss impact analysis and investigations
	Productivity
	Temporary works and traffic management
	Number of Requests for Information (RFIs) and WSCs
	Lessons learnt

8.3.1 Establish context

Figure 8.5 shows the CLD of establishing context developed by Vensim software. It visualises the variables that positively and negatively influence the recovery systems in establish context stage.

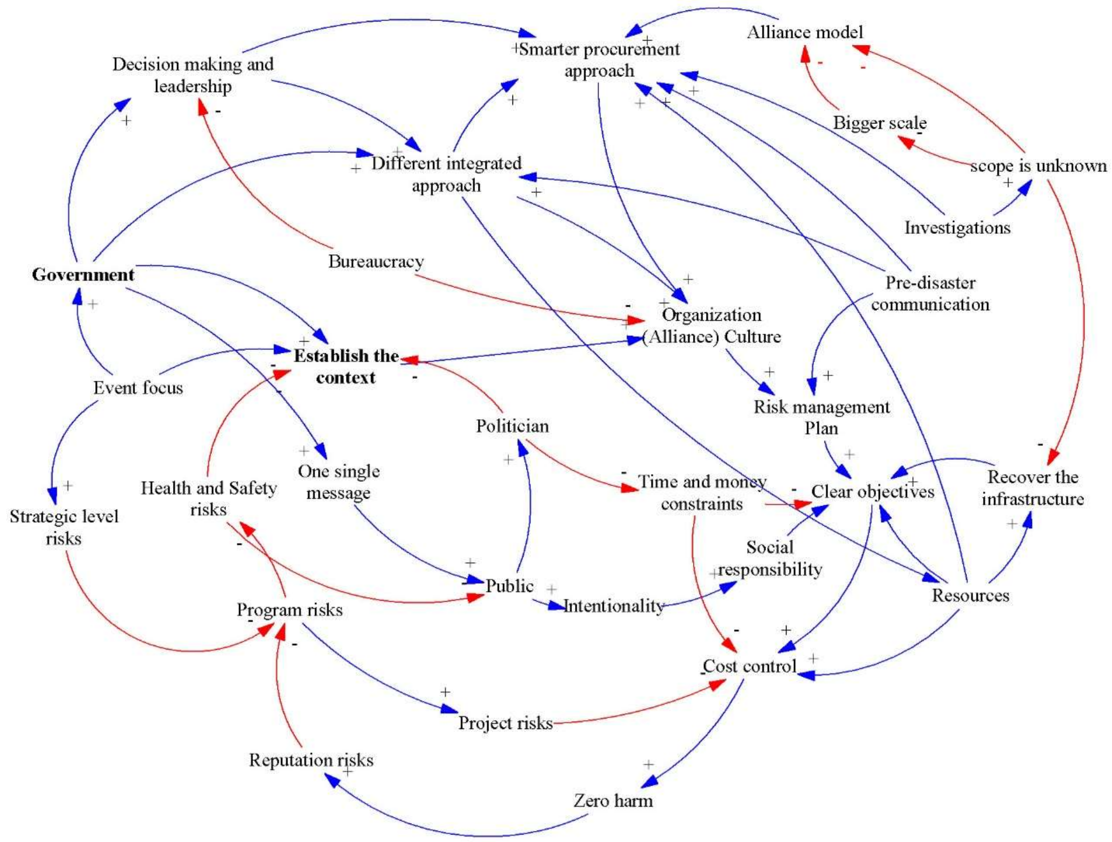


Figure 8.5: CLD of establishing context by Vensim software.

Based on the participants' inputs in “Appendix E, Header 1”, establishing the context in recovery projects is event focused and is influenced by an understanding of the situation and the scale after the disaster; pre-disaster planning of the post-disaster risks; clear organisational and risk management objectives. In addition, good risk management leadership that endorses quick decision making; good intentionality of all parties to deliver the programme and help the city recover from the disaster and maintain the public and political involvement; strong shift in culture towards effective PDRM, and good procurement strategy with integrated information and project management systems.

8.3.2 Risk assessment

Risk assessment is the second step in risk management, according to ISO31000. It contains risk identification, risk analysis and risk evaluation. Figure 8.6 represents the CLD of risk assessment in the recovery projects based on the participants’ responses in “Header 2”.

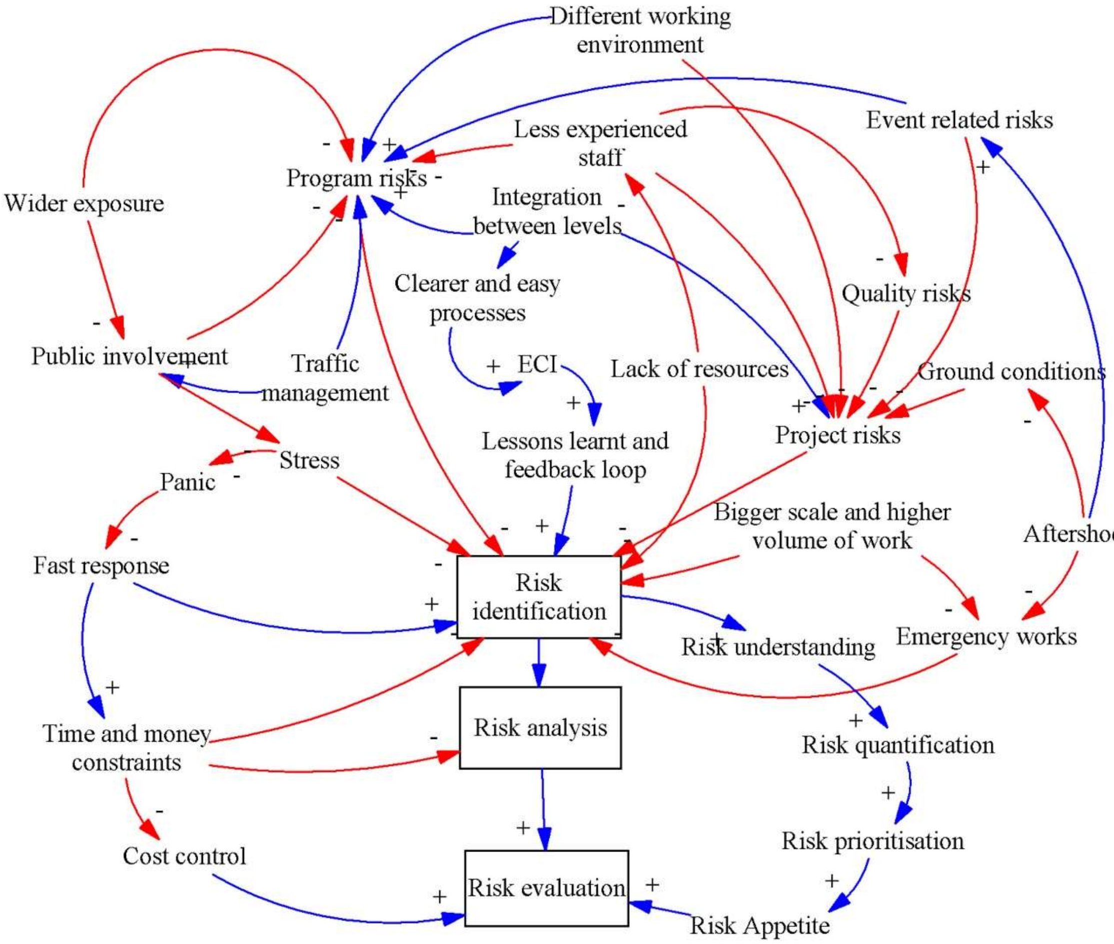


Figure 8.6: CLD of risk assessment.

After analysing the participants' inputs "Appendix E, Header 2", risk assessment in the recovery projects appears to be driven by a broader and larger scale of work involved, which required integration between levels, and the emergency works, which required fast-track procedures and risk prioritisation for a quick response. Nevertheless, it needs to consider the challenges of having different working environments, different risk profiles and risks hard quantifying due to the unclear scope and unforeseen. In addition, a better understanding of the risks and the emotional involvement associated with them, which include high-stress levels and the importance of learning lessons from previous projects in the same programme, and the feedback loop to share the knowledge and avoid delays.

8.3.3 Risk treatment

Based the participants' responses in "Appendix E, Header 3", Figure 8.7 presents the variables that influence the risk treatment in the recovery project.

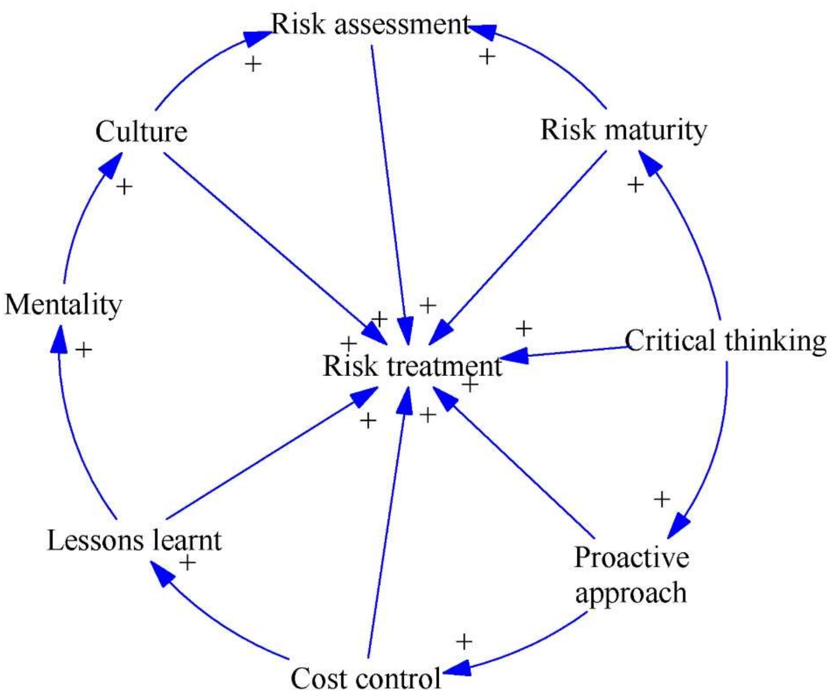


Figure 8.7: CLD of risk treatment.

The risk treatment in recovery projects requires a proactive approach where lessons learnt from earlier projects in the same programme were endorsed by evaluation procedures, feedback loop and knowledge sharing between all parties. In addition, critical thinking to change the culture and the mentality of the team is essential for better cost control and more effective risk treatment.

8.4.4 Monitoring and controlling

After going through the common variables that influence the monitoring and controlling in the recovery project based on participants' responses in "Appendix E, Header 4", it was clear that a combination of external and internal audit approaches for risk management in recovery projects is highly recommended. For external audit, it is recommended to be at the beginning of the recovery programme with enough frequency to ensure the application of the best practices for an effective PDRM. The external audits provide new ideas, sharing the knowledge and endorsing new staff to apply the right risk management procedures. Moving forward on the recovery programme, the external audit frequency should be decreased and replaced by internal audit to avoid time delays and cost increase. Figure 8.8 represents the CLD of monitoring and controlling in recovery projects.

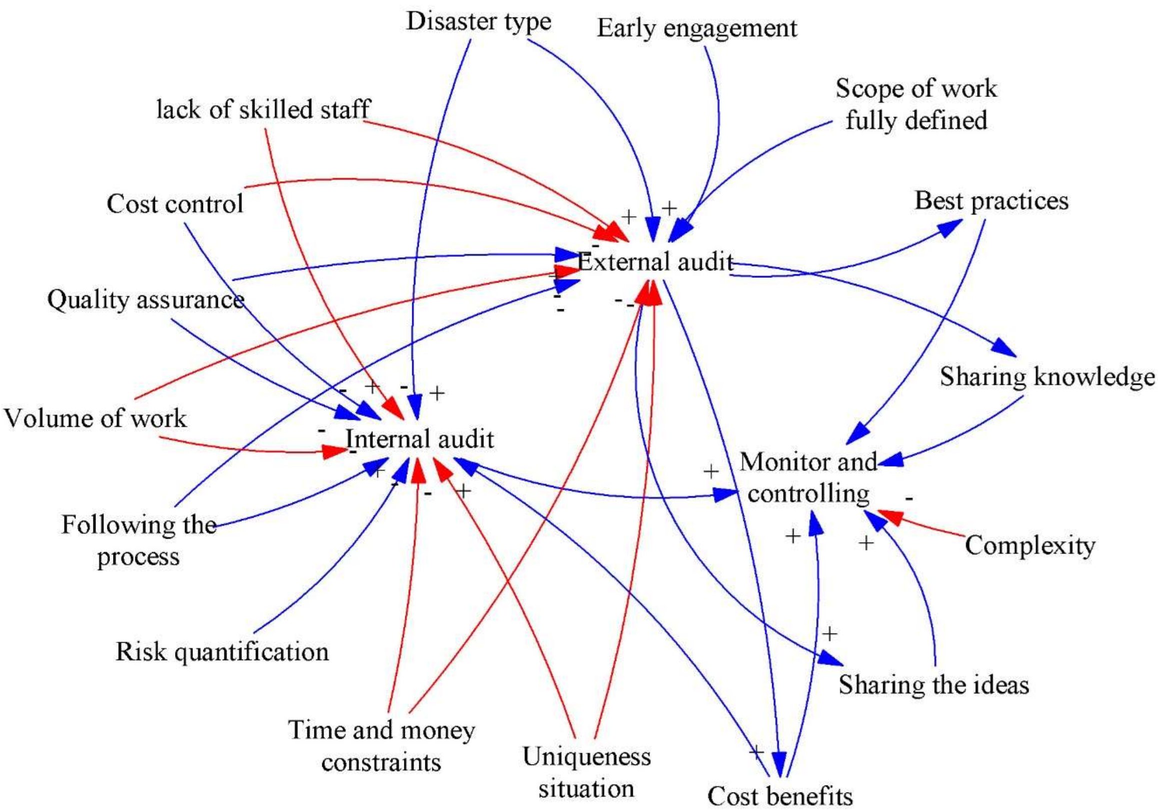


Figure 8.8: CLD of monitoring and controlling.

8.3.5 Communications in recovery projects

Communication is the fifth vital element of the risk management process in ISO31000. Figure 8.9 represents the CLD of communications in recovery projects.

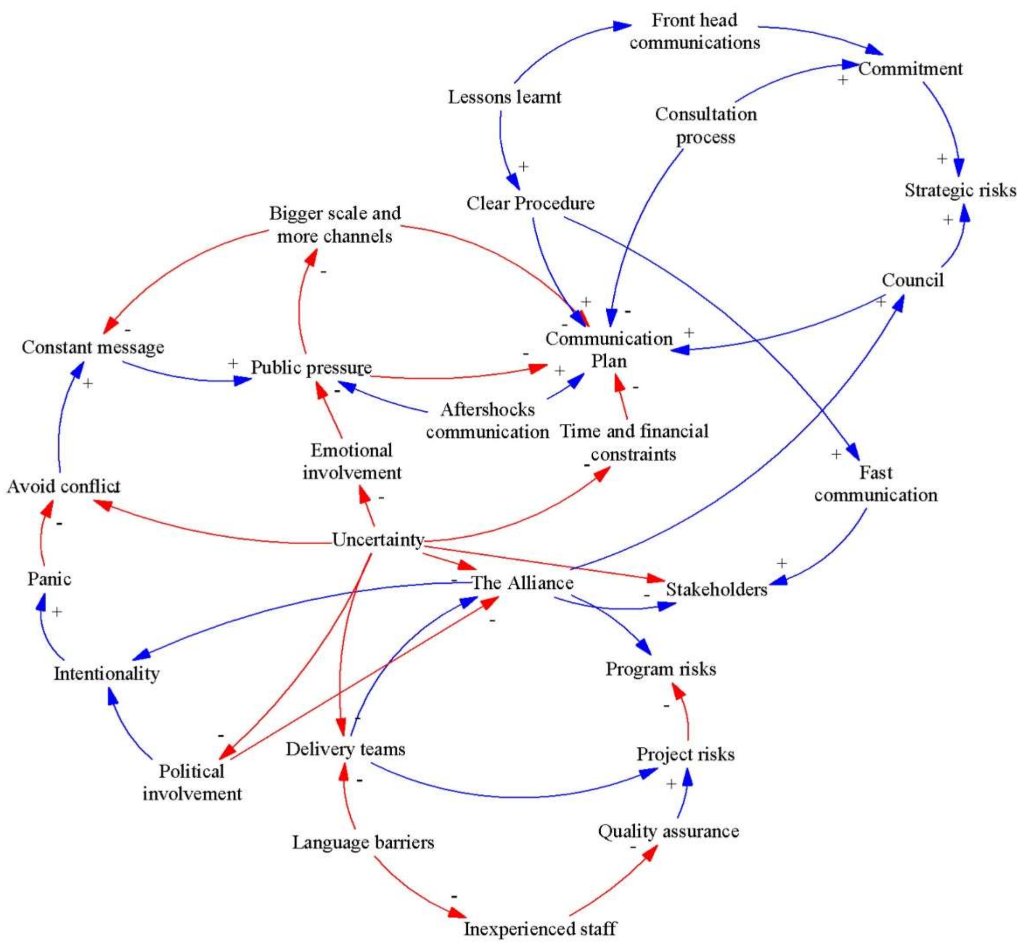


Figure 8.9: CLD of communications in recovery projects.

Based on the participants' responses in "Appendix E, Header 5", the communication in recovery projects is more complex than BAU due to the large number of stakeholders in recovery projects, which dramatically increase the number of communication channels. Also, due to political, public and media high involvement, communication becomes more sensitive. Therefore, it needs to involve clear intentionality to meet people's expectations, taking into consideration the irritation, which requires emotional intelligence from the recovery organisations with aftershock communication. Communication needs to be faster by cutting the regular consultation process and be ahead of the game to avoid any conflict or frustration, due to the time and financial constraints. Also, it requires taking into consideration the language barriers generated because of the mixed backgrounds and culture of the recovery teams and the public.

8.3.6 Resources in recovery projects

Resources in recovery projects represent a key concept in risk management based on the participants' responses in "Appendix E, Header 6". Figure 8.10 represents the CLD of resources in recovery projects.

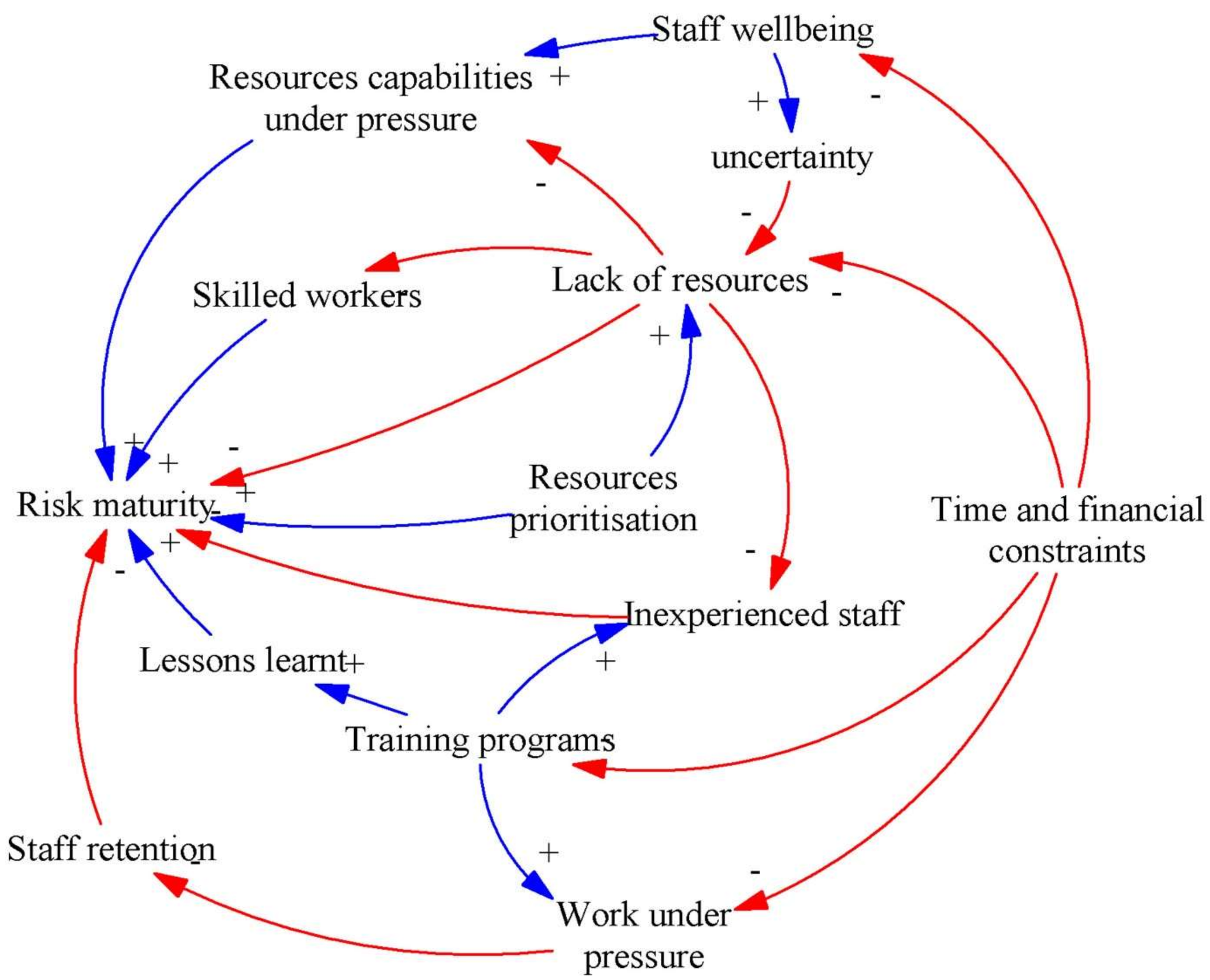


Figure 8.10: CLD of resources in recovery projects.

Participants in "Appendix E, Header 6" believed that resources in recovery projects are more challenging than in BAU; it is influenced by emotional and human factors that are related to the disaster situation, which highlighted the importance of emotional intelligence to deal with such resources. Nevertheless, a huge lack of resources is considered to be one of the bigger risks in recovery projects.

This lack of resources puts the industry at a risk of having inexperienced staff who are working under pressure, which increases the human error compare to BAU. Also, it affects the quality and increases the risk profile. Therefore, it is important to consider resource prioritisation, measure team capabilities and adopt staff wellness programs in recovery projects to avoid staff retention and achieve the programme objectives.

8.3.7 Culture after the disaster

Culture also was an important concept in PDRM based on the participants' responses in "Appendix E, Header 7". Figure 8.11 presents the variables that influence the culture after a disaster in a CLD.

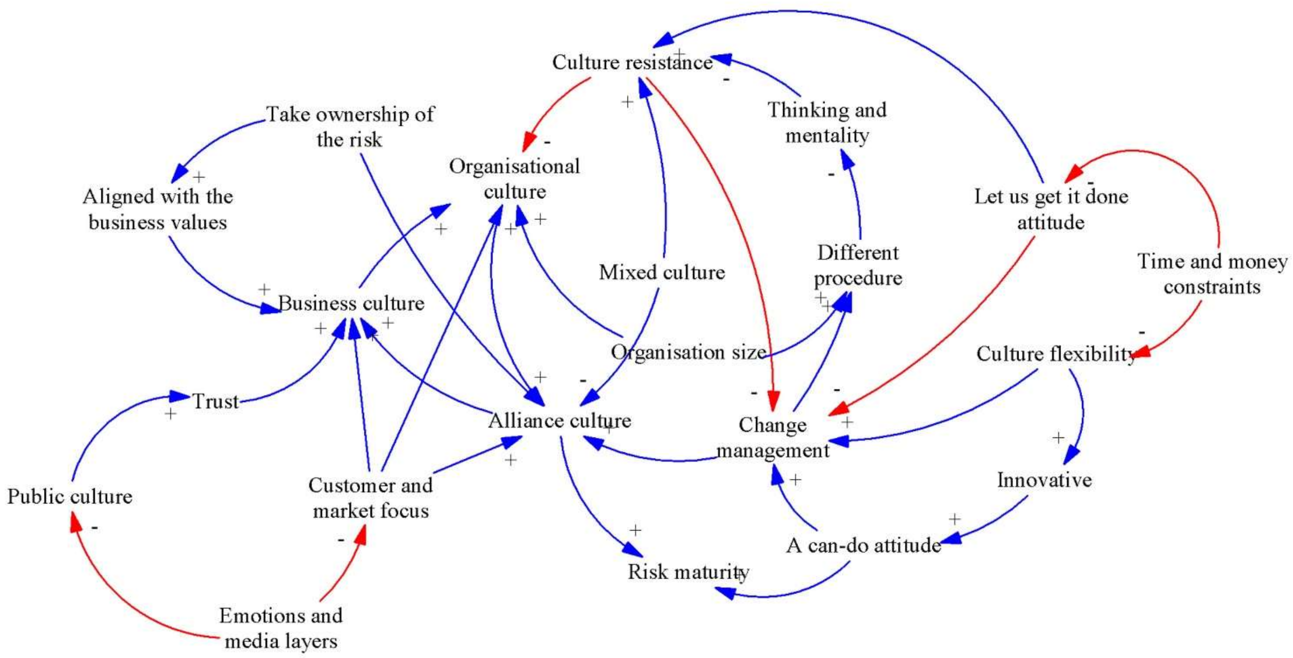


Figure 8.11: CLD of culture after the disaster.

It appears that recovery organisations should focus on shifting the culture of the recovery staff towards a better awareness of event-driven risks, and the factors influencing the PDRM efficiency. Also, recovery organisation should be taking into consideration the overlap of business culture, company culture, and public culture and the interactions between these cultures to serve the recovery programme goals. Nevertheless, it is essential to consider the influence of the company's size, and the drivers behind the culture attitude. Also, it is important to maintain resilience by having enough flexibility to manage the mixed culture after a disaster and overarching this mix with one common recovery culture.

8.3.8 Building Trust

Trust was identified as a critical concept that hugely influences the PDRM based on the participants' responses in "Appendix E, Header 8". Figure 8.12 illustrates the variables that influence trust in recovery projects as a CLD.

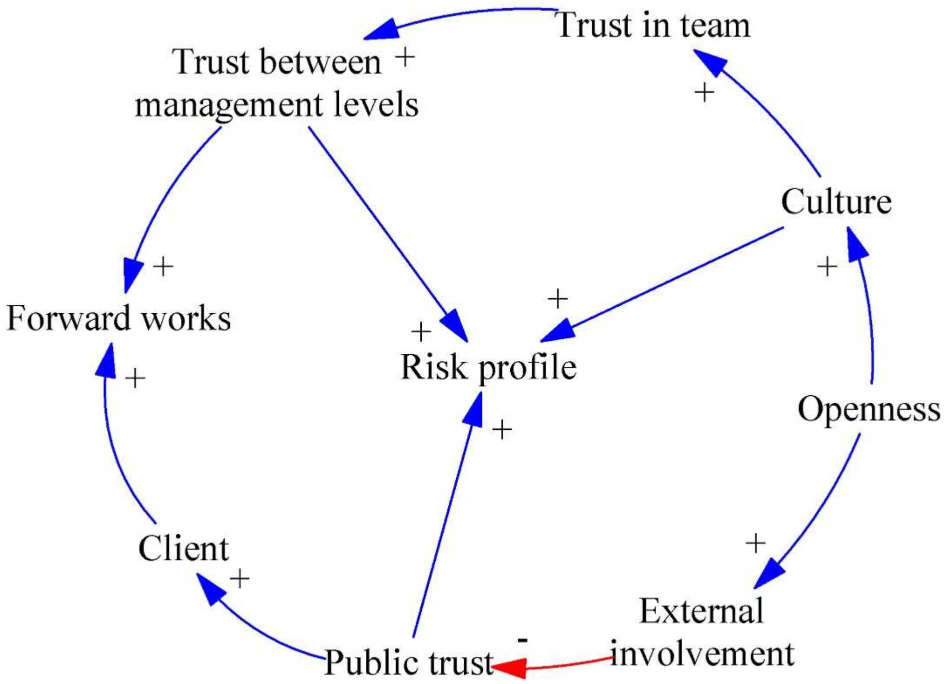


Figure 8.12: CLD of trust.

Based on participants' responds in "Appendix E, Header 8", it appears that trust is one of the facets of decision-making in PDRM. There are different dimensions of trust in recovery projects, including public trust, trust between management levels, trust inside the recovery team and the trust of work continuity. Moreover, Trust is an attempt to shape the relationship between all the different layers of recovery parties from the client, recovery management, delivery teams, and to the end user.

These types of trust could be illustrated by various examples from the SCIRT case study. For example, the trust between the client and the delivery teams, which was built by developing a contractual alliance model that caught the attention of the delivery team with low risk, the pain/gain model. The public trust can be increased by honest and effective communication, taking into consideration the emotional dimension of the situation. Also, building the trust inside the team by considering their wellbeing and human factors, and the development of their culture to improve the risk awareness and to secure their fears regarding future work. It is important to build a strategic trust plan which covers all these factors to avoid any frustrations or delays to the recovery programme.

8.3.9 Complexity levels after a disaster

Based on the participants' responses in "Appendix E, Header 9", the complexity in recovery projects increased dramatically compared to BAU. Figure 8.13 summarises the variables that were driving the complexity level in recovery projects in a CLD. The increase of complexity is due to the huge number of stakeholders involved, such as governmental organisations, politicians, the public, third party insurance and the media. Moreover, the recovery projects appear to be dynamic with continuous changes in regulations, and standards, which lead to design changes. Nevertheless, the recovery projects are steered by prioritisation, which could change the risk appetite for the recovery organisation anytime.

In addition, recovery projects are associated with different dimensions of emotional and social impacts national wide, which required emotional intelligence interaction. These projects are considered significant and critical with time and money constraints. Therefore, these projects required more critical thinking and complicated procedures than BAU to break down the complexity.

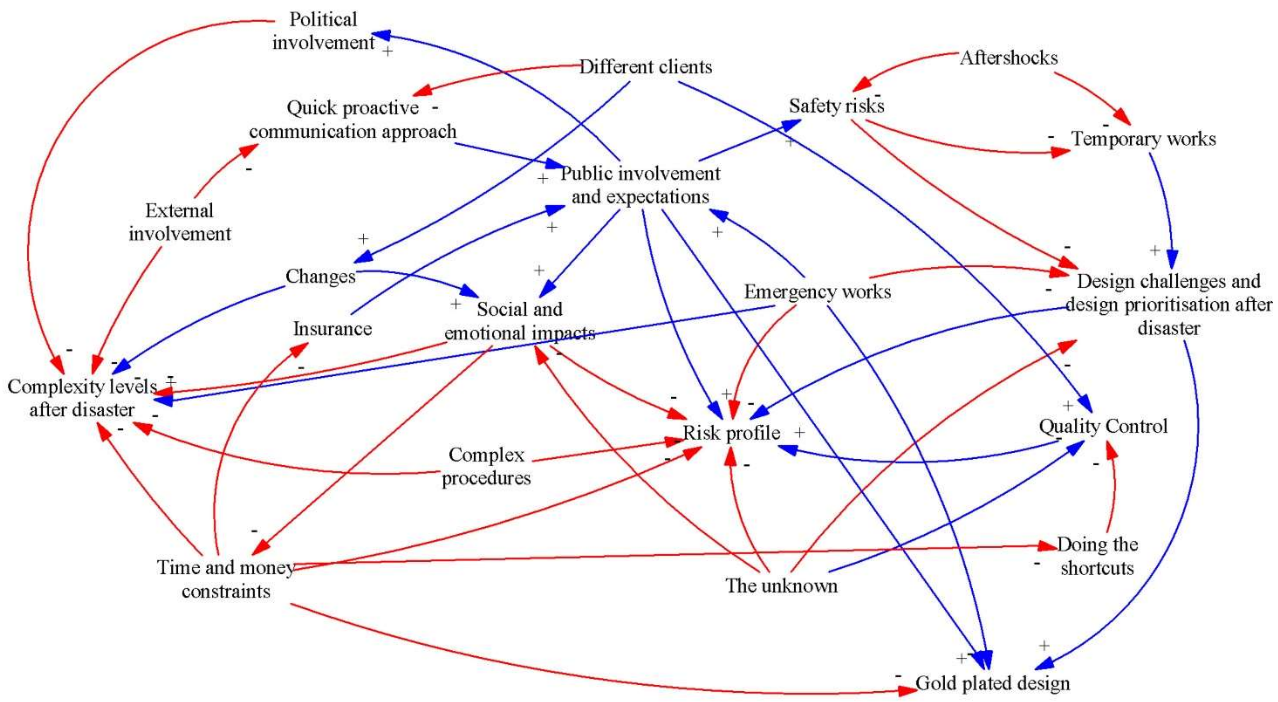


Figure 8.13: CLD of complexity after disaster.

8.3.10 Public engagement and emotional intelligence

Public engagement is one of the main concepts in recovery projects based on the participants' responses in "Appendix E, Header 10". Figure 8.14 summarises the variables that drive public engagement in recovery projects.

It appears that recovery projects are characterised by a huge range of public engagement with high emotional and sensitive psychology. The public involvement is so deep to the degree that they could be described as a secondary client. Most of the recovery work is done under their sight and indirect supervision, as the working environment contains them, and recovery organisations are accountable for their safety.

Most people after a disaster are under stress. They are trying to recover from the disaster emotional and mental impacts; therefore, people may act differently. Both the public and the team would act differently, the public is irritated, and staff are under stress to meet the public expectations. This level of emotions required a certain level of emotional intelligence.

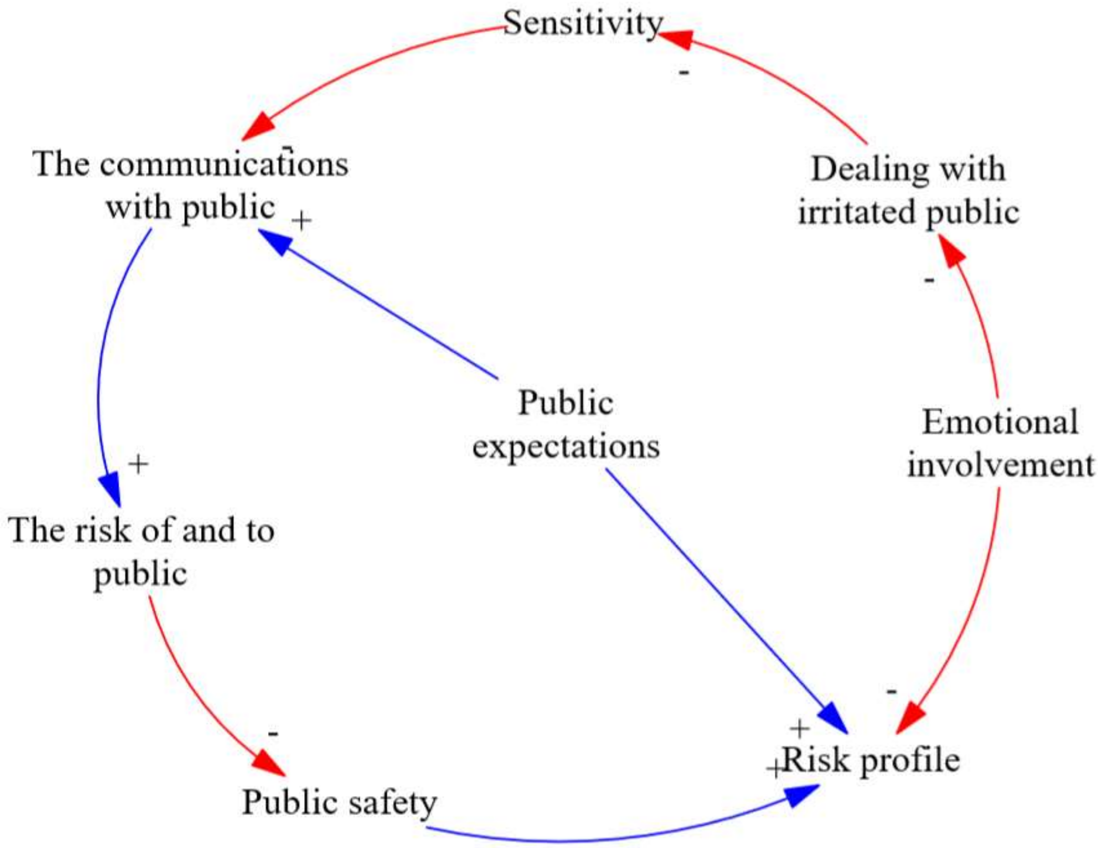


Figure 8.14: CLD of public engagement.

8.3.11 Different market after a disaster

Based on the participants' responses in "Appendix E, Header 11", the market after a disaster is quite different than before a disaster due to the environmental and socio-economic changes and impacts associated with a disaster. The market after the disaster appears to be so different prior to the disaster. With the recovery alliance in place, the competition in the market seems to be less, as the volume of work has been huge. In addition, the disaster has changed the environment, which has generated a unique situation. On the other side, new opportunities arise; which encouraged so companies to shift their business core to construction with limited experience, just to take advantage of the booming market. Figure 8.15 summarises the variables that drive the market in recovery projects represented in CLD.

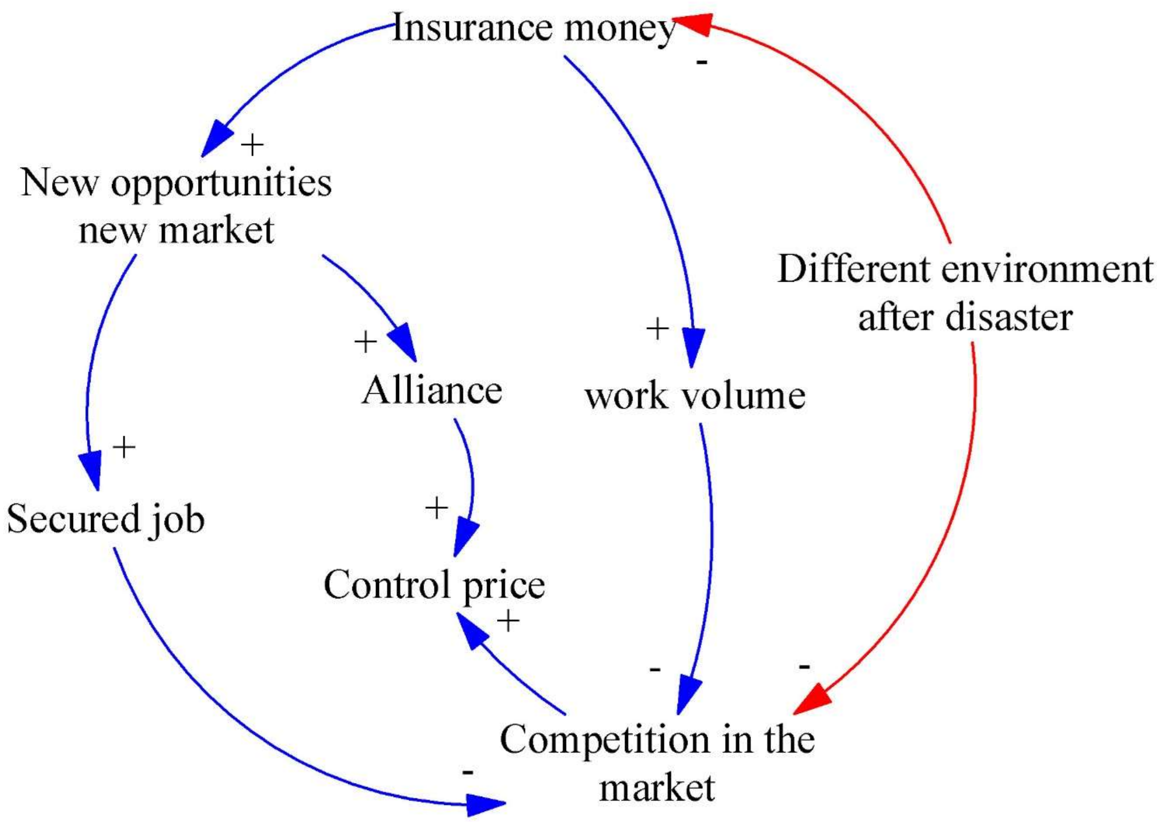


Figure 8.15: CLD of the market.

8.3.12 Different risk profiles

Based on the participants' responses in "Appendix E, Header 12", the risk profile in recovery projects is also different from BAU. Risks become more event-related risks, but it depends on the type of disaster. Risks in recovery projects are combined with a high level of emotional and social involvement with wider exposure, which could affect the recovery organisations' reputations. This requires a more proactive communication approach. In addition, the uncertainty levels are high because of the undefined scope, and unforeseen ground conditions, which require better investigations and understanding of the staff capabilities and human factors to help in better decision making. Figure 8.16 summarises the variables that drive the risk profile in recovery projects represented in CLD.

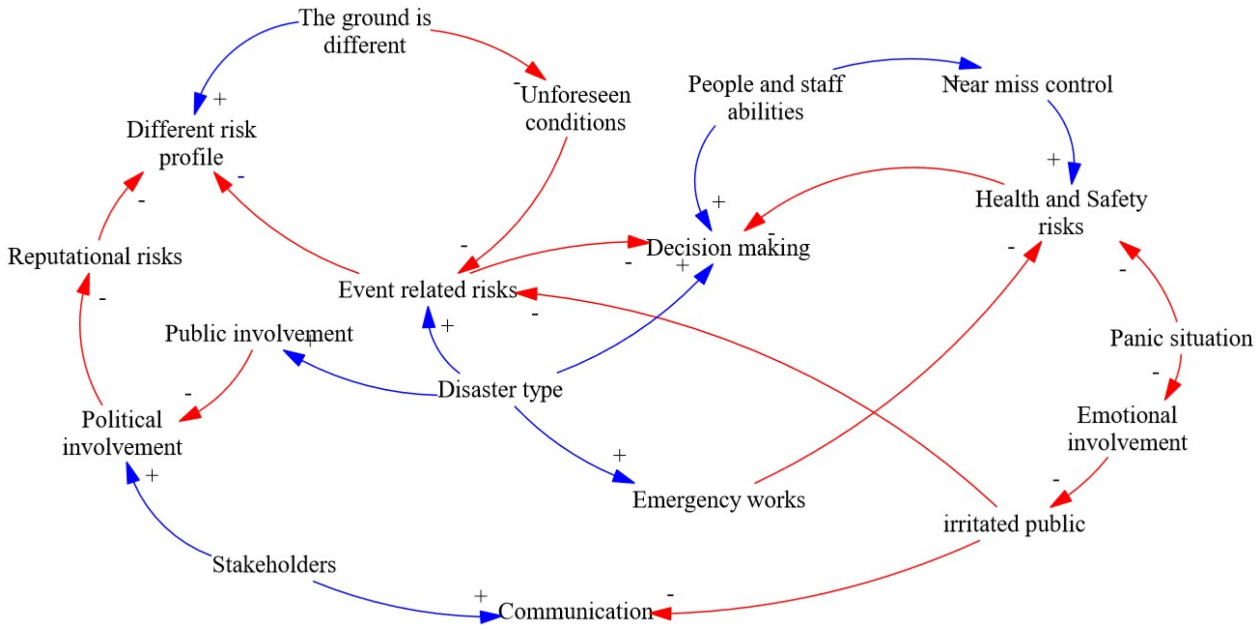


Figure 8.16: CLD of the risk profile.

8.3.13 Risk Management Maturity (RMM) in recovery projects

Based on participants' responses in "Appendix E, Header 13", RMM is a vital concept in recovery projects. Figure 8.17 illustrates the variables that influence the RMM in recovery projects represented in CLD.

It appears, due to time and financial constraints, there were no numerical RMM measures in SCIRT programme; however, as has been investigated in chapter 7, some KPIs are positively linked to RMM. Participants in "Appendix E, Header 13" believed that the leadership and the responsibility of increasing the risk awareness supported by a better understanding of the surroundings inside the recovery programme are essential factors to increase the RMM in recovery projects. Also, endorsing the risk management procedures, and internal and external audits, which include clear lessons learnt, or a feedback loop are important factors. Also, there is a need to have strong document controls and an intelligent information system.

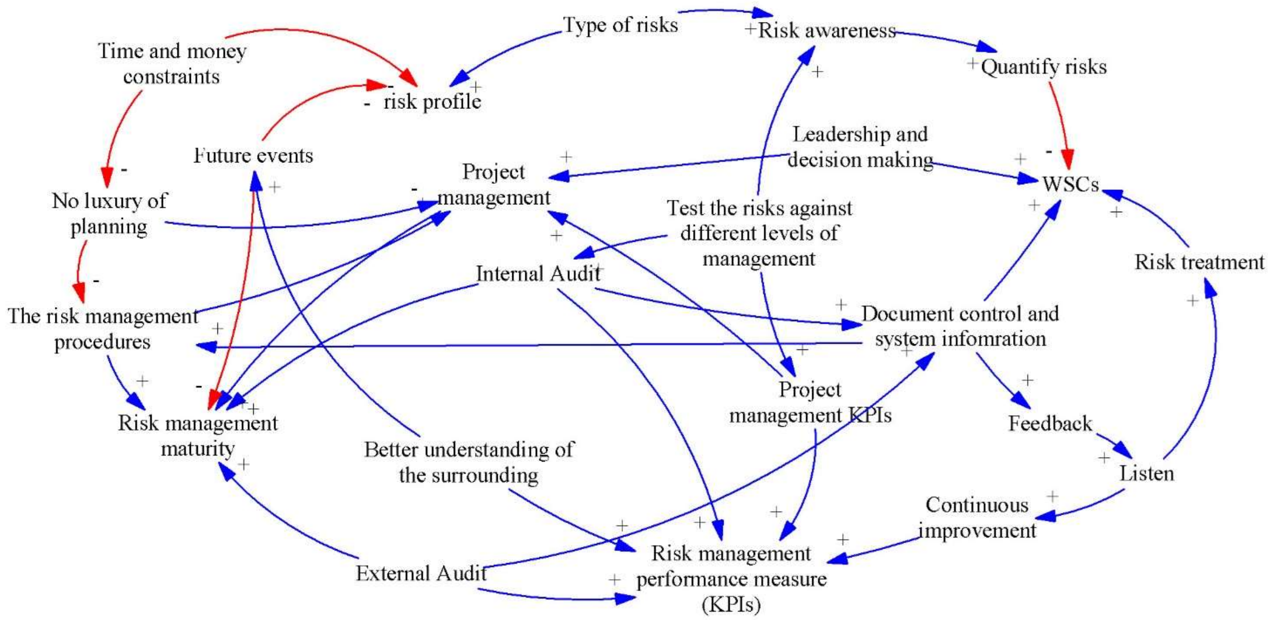


Figure 8.17: CLD of RMM.

8.3.14 Quality Control (QC) and Quality Assurance (QA) in recovery projects

Quality control (QC) and Quality Assurance (QA) have been identified as important concepts in recovery projects based on participants' responses in "Appendix E, Header 14". Figure 8.28 shows the variables in QC and QA and its influence on overall risk management represented in CLD.

QC & QA in recovery projects are clearly linked and influenced by trust, culture, internal audit, lack of resources, and time constraints. Due to time and financial constraints, the self-quality performance approach has been promoted in SCIRT to avoid any delays. However, with the lack of experienced staff and lack of training, the quality appears to be affected, and lots of rework was needed. It has been interpreted from the participants that more investigations with enough training for the staff and frequent external audits with lessons learnt, besides a robust internal audit system could be the solution for better quality outcomes in recovery projects.

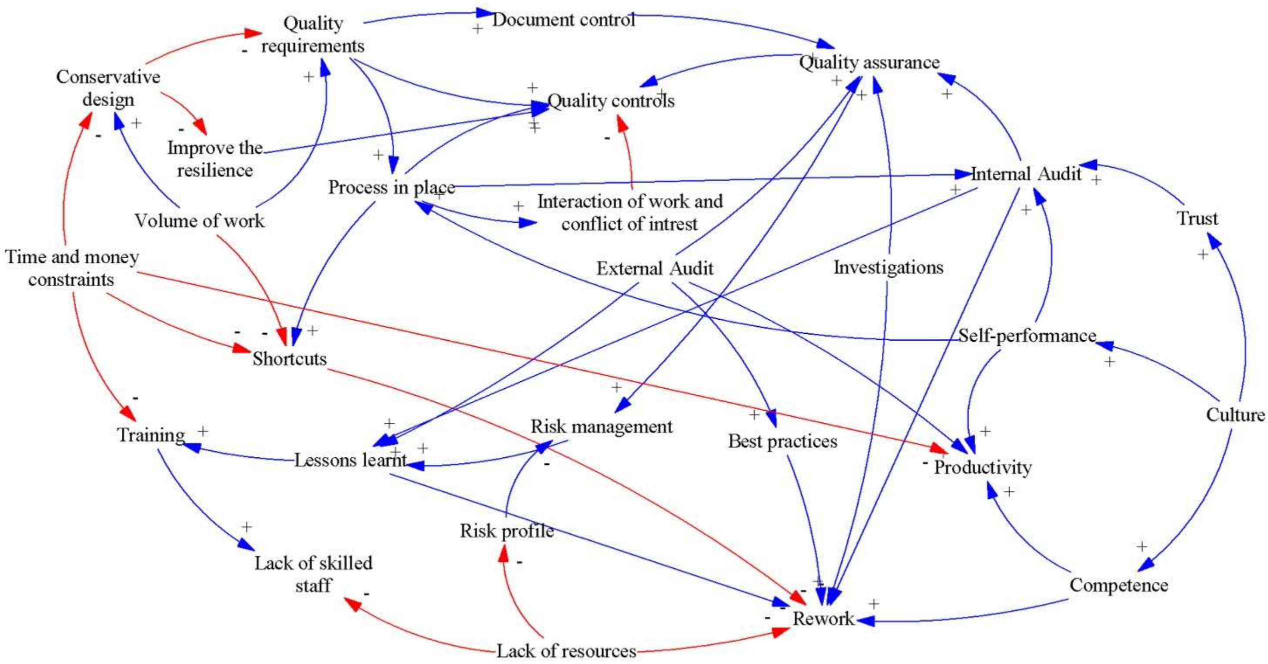


Figure 8.18: CLD of QC & QA node.

8.3.15 Risk management approach "Centralised vs. decentralised approach"

Based on the participants' responses in "Appendix E, Header 15", both centralised vs. decentralised risk management approaches in recovery projects were identified as key concepts in recovery projects. Centralised approach referred to risk management functions in the organisation being controlled and managed by one person or one team; however, the decentralised approach refers to the risk functions managed by all of the project team. Figure 8.19 shows the variables that influence the risk management approach in recovery projects represented in CLD.

It has been noticed that a mixture of centralised and decentralised risk management approaches is more effective in recovery projects where combined benefits could be achieved. The benefits of having centralised governance controlling the risk procedures and directing the people toward effective risk management and best practices. Decentralised approach, with collective ideas, share the knowledge and the skills to deal with onsite risks, which endorse quick decision making and avoid delays.

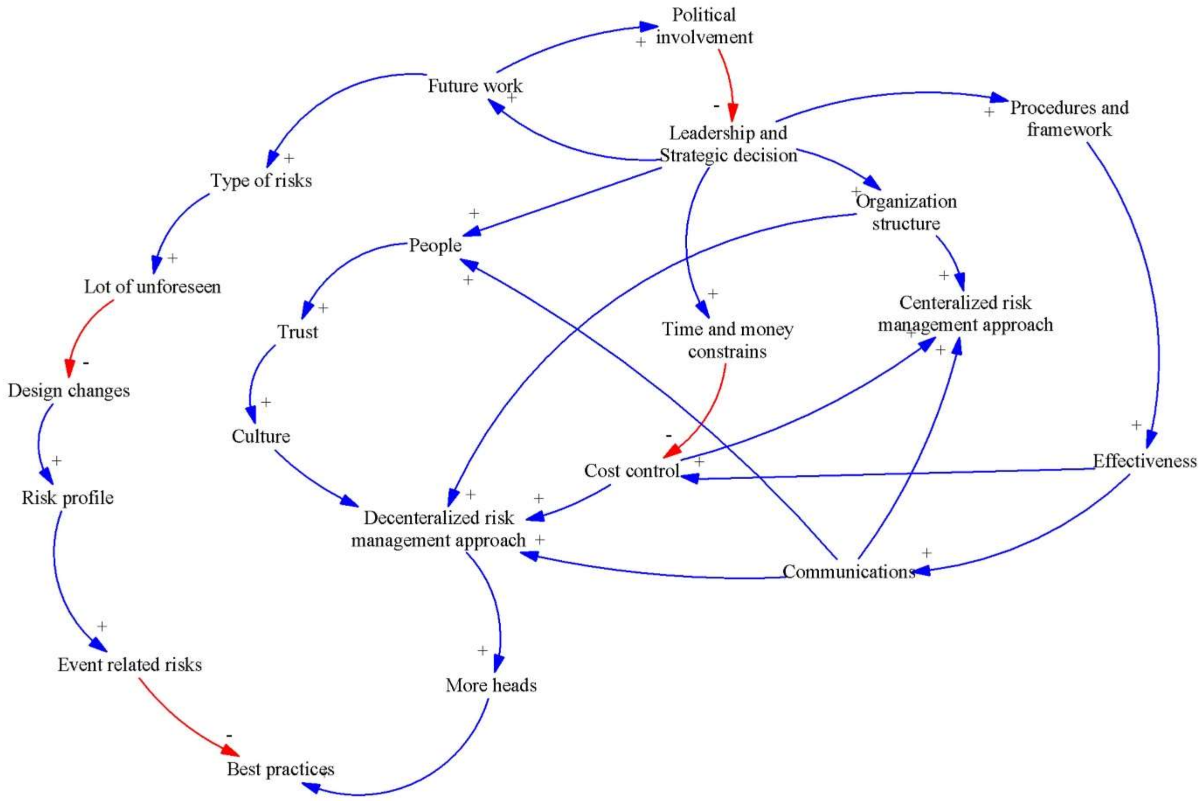


Figure 8.19: CLD of a centralised vs. a decentralised approach.

8.3.16 Prioritisation strategy in recovery projects

The prioritisation strategy has been highlighted by the participants “Appendix E, Header 16” as one of the critical concepts for more effective risk management in recovery projects. Figure 8.20 represents the variables that drive the prioritisation concept in recovery projects.

Prioritisation strategy becomes critical in recovery projects due to the emergency works required after a disaster associated with time and financial constraints. The CLD of prioritisation in recovery projects (Figure 8.20) shows that to meet the planned time and budget; there is a critical need to follow a prioritisation strategy at all levels. The participants declared three levels of prioritisation, work prioritisation, resources prioritisation, and risk prioritisation. These prioritisation levels should be promoted, driven and regularly updated by the recovery leadership and clearly communicated to all the management levels.

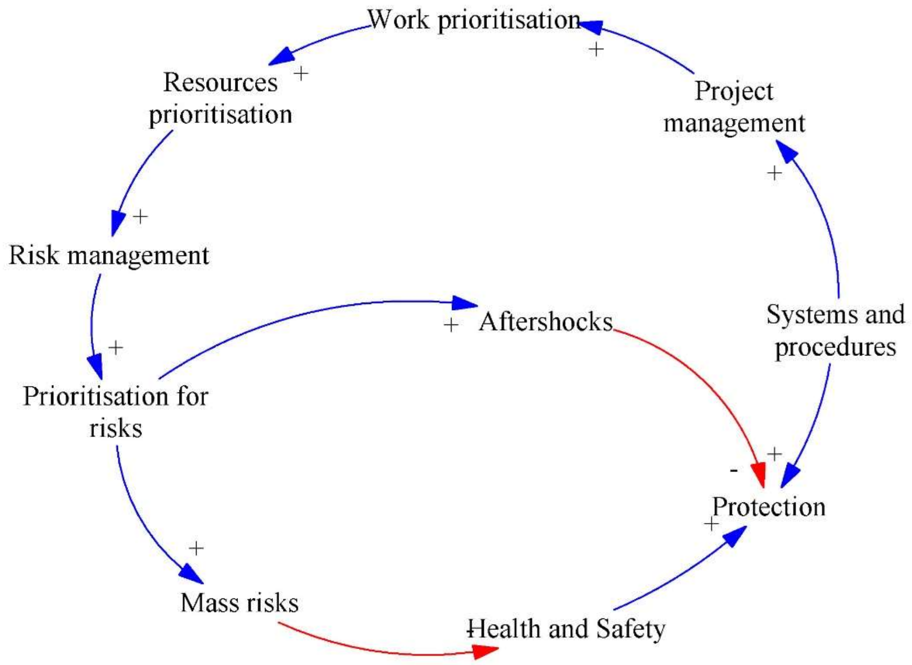


Figure 8.20: CLD of prioritisation.

8.3.17 Undefined scope of work and uncertainty levels in recovery projects

One of the common concepts from the participants' discussion in "Appendix E, Header 17" is the high level of uncertainty and unforeseen risks in most of the recovery projects. Figure 8.21 highlights the common variables that influence uncertainty and unknown in recovery projects in CLD.

The discussion with the participants showed that there were limited investigations, especially at the beginning of the programme due to time limitations and emergency work. Moreover, the massive volume of work with high pressure from the key stakeholders, such as the government, the media and the public added more pressure to deliver projects. That created a unique programme where the recovery organisation was forced to do work concurrently and even started some projects without enough investigation or a clear scope of work.

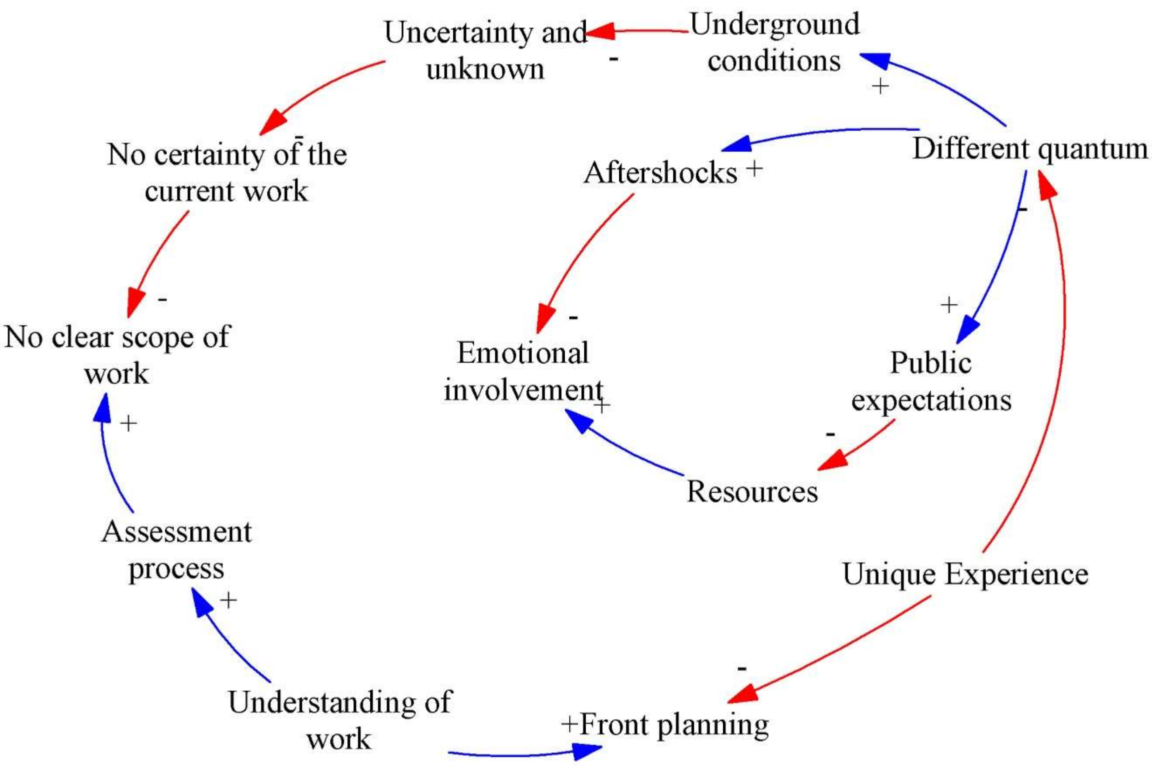


Figure 8.21: CLD of uncertainty and unknown.

8.3.18 Interaction and conflict of interest in recovery projects

Based on the participants' responses in "Appendix E, Header 18", one of the common concepts in the recovery programme is the different layers of interactions. As per Figure 8.22, it has been found that the interactions in recovery projects are complex. These interactions happen across and between different layers of management and different dimensions of stakeholders. For instance, the interaction between different sectors, such as the public and private sectors. The interactions of workload between delivery teams working in the same area inside the same recovery programme and even organisations from outside the programme. For example, the interactions between residential recovery organisations and infrastructure recovery organisations in the same area. In addition, the interactions between project phases, as most of the projects need to work concurrently to deliver the programme on time. All these layers of interactions require a high level of cooperation and effective systems and procedures in place. These systems need to be flexible enough to avoid any conflict and ease the friction between all these layers. Nevertheless, it is vital to align the cultures of all parties to a one overarching culture that endorse better cooperation and direct the effort to the desired outcomes.

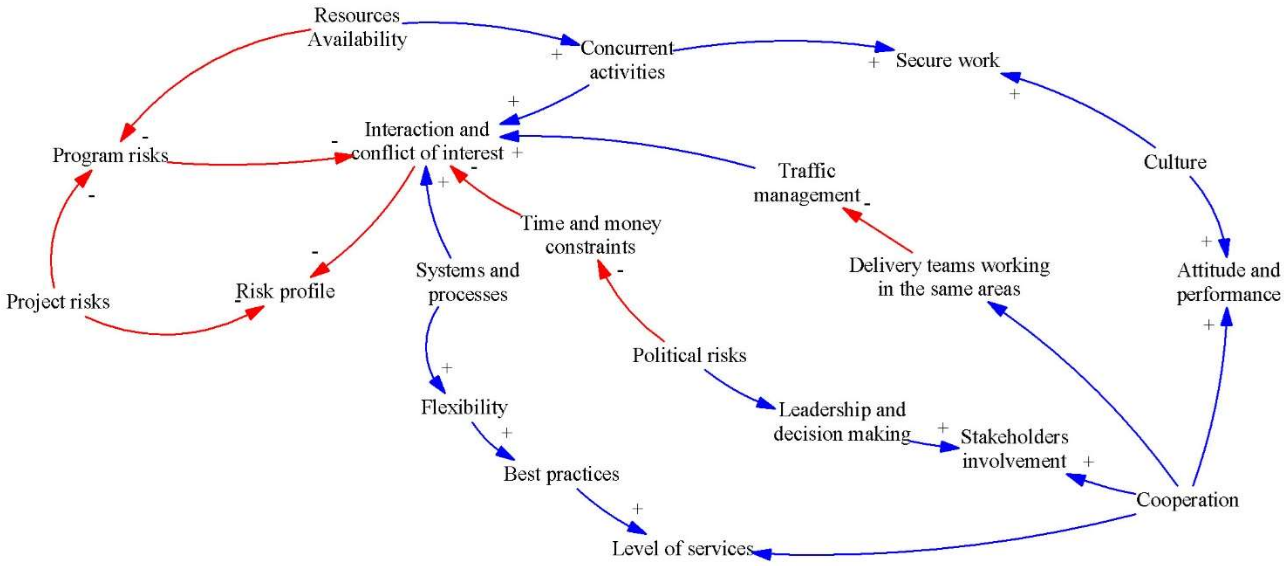


Figure 8.22: CLD of interaction.

8.3.19 Processes, legal changes and consents

Based on the participants' responses in "Appendix E, Header 19", the processes, legal and standards changes, and consents are common concepts that profoundly affect the risk management inside the recovery projects.

As per the CLD of regulations and processes in recovery projects (Figure 8.23), it has been found that recovery projects are subject to several continuous changes throughout the programme lifecycle. For example, there is a high chance that standards, regulations, processes need to be updated after a disaster. The number of changes appears to create a dynamic recovery system that requires an effective communication strategy and culture shift to endorse the adorability and adoption of the changes. Besides, it required smarter procedures and effective training programs for new and experienced staff to enable the programme delivery more effectively.

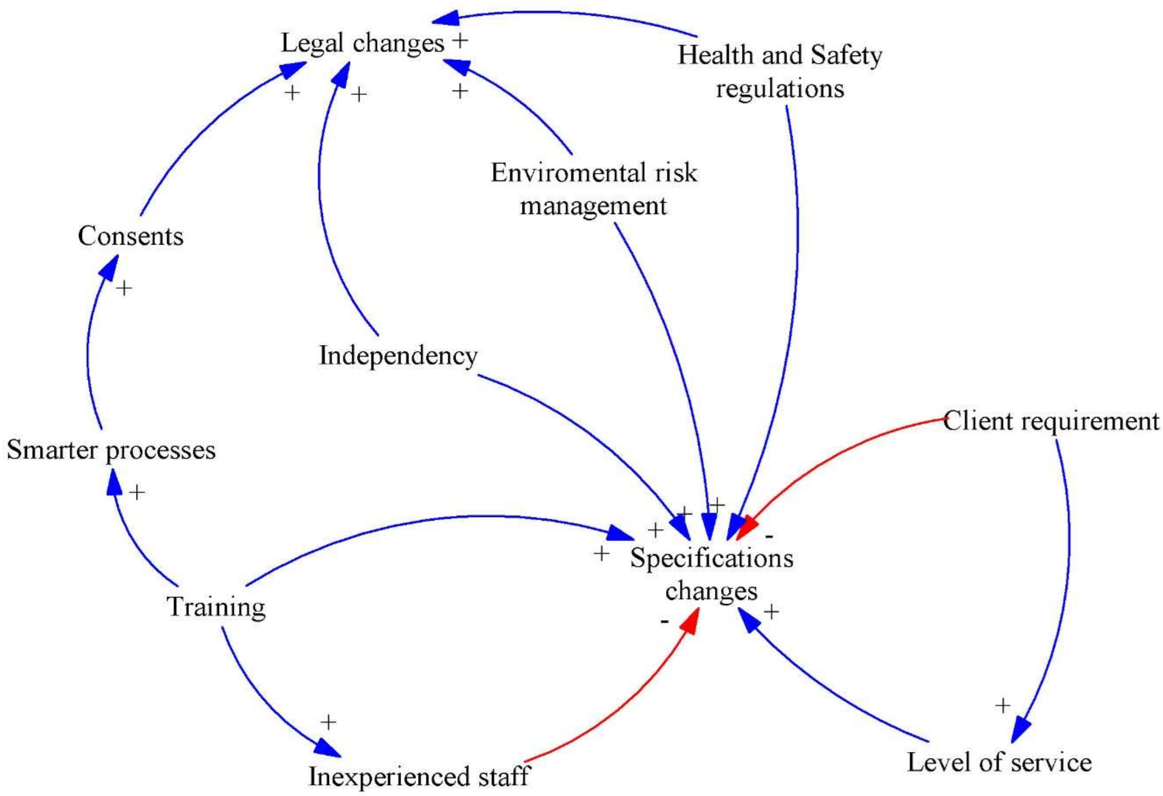


Figure 8.23: CLD of processes and legal changes.

8.3.20 Leadership and decision making

As per the outcomes from the participants' engagement "Appendix E, Header 20", leadership and decision-making have been identified as a major concept in recovery projects. Figure 8.24 represents the leadership and decision-making CLD in recovery projects.

Participants agreed that recovery projects are in a critical need for effective leadership with front strategic planning skills and quick decision-making abilities. Also, it is important for the leadership to build up a team working environment from the right people with the right skills to achieve the desired goals and objectives. In addition, the success of leadership in recovery projects is positively influenced by choosing the right intelligent systems, developing fast track procedures, endorsing innovation ideas that could save time and money in the recovery programme, and listening to the market needs after the disaster.

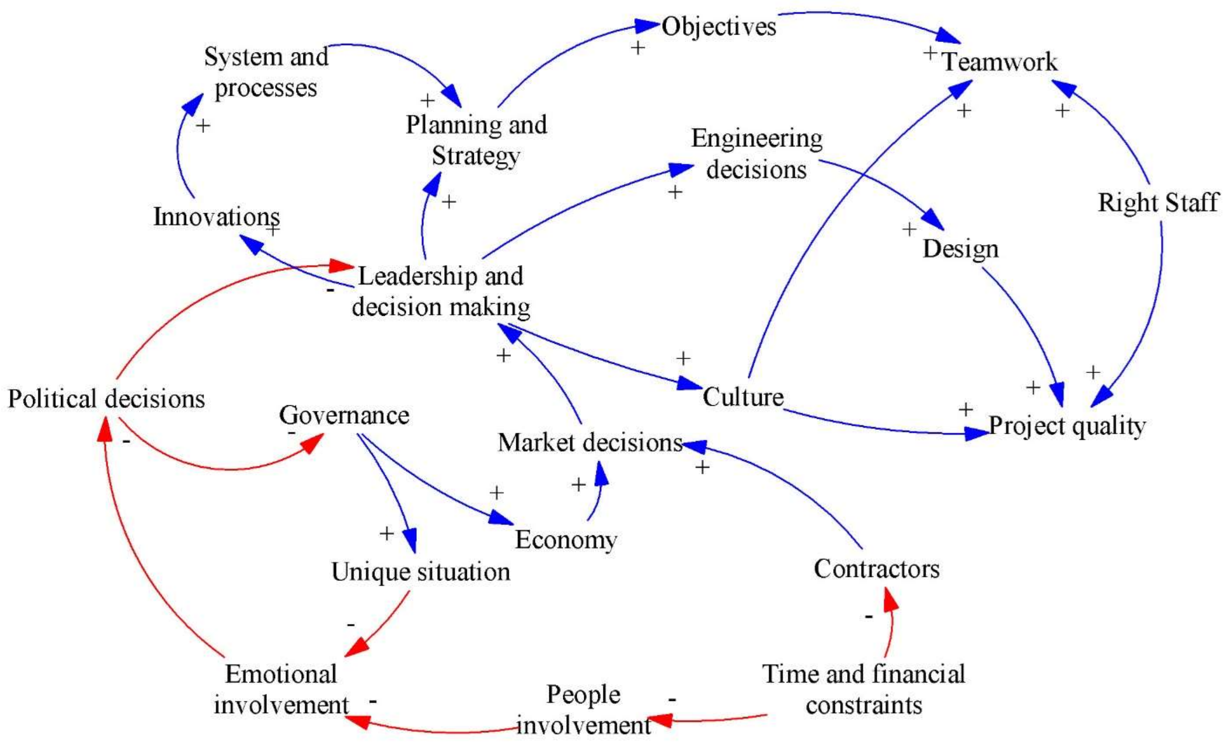


Figure 8.24: CLD of leadership.

8.3.21 Disaster and project types

Based on the participants' responses in "Appendix E, Header 21", disaster and project type were identified as important concepts that influence the risk management in recovery projects. Figure 8.25 represents CLD of disaster and project types in recovery projects.

Participants believe that the combination of the impact of a disaster on the environment and what that means for the team to operate in this environment. For example, for a disaster like an earthquake, participants highlighted the high amount of risks under the ground even with enough investigations. Also, the disaster type gives a holistic indicator of the type of projects that would be required for the recovery programme; for example earthquake hitting infrastructure would require roads and network repairs projects. That is why the type of disaster influence positively the project type in the CLD. Also, participants have linked the complexity of a project to the number of risks this project is facing.

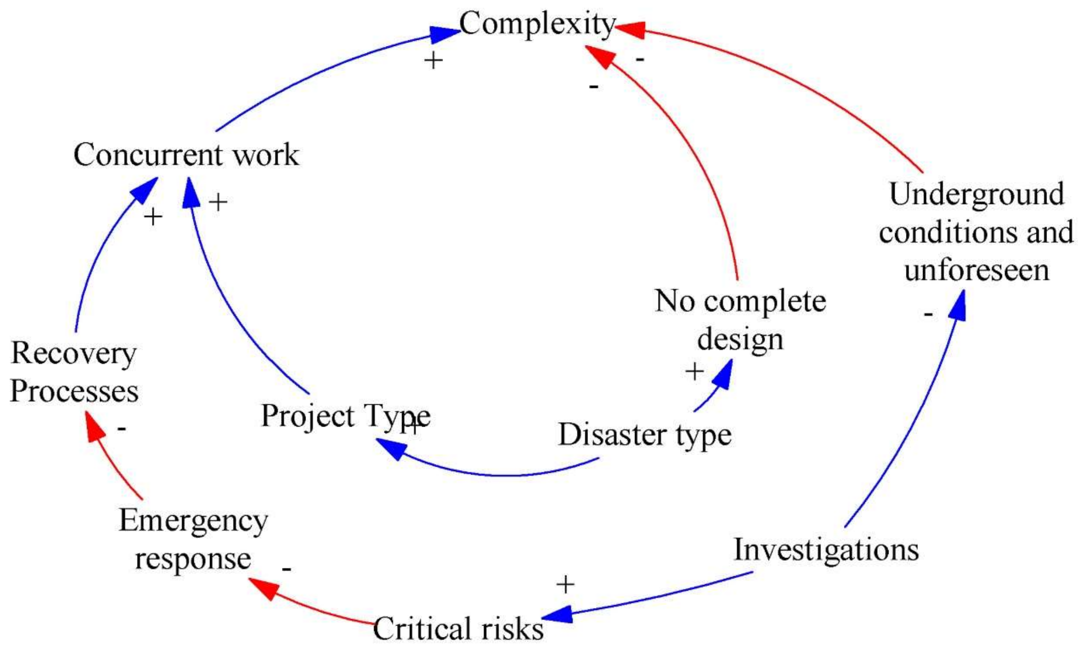


Figure 8.25: CLD of disaster and project types.

8.3.22 Loss impact analysis and investigations

Based on the participants' responses in "Appendix E, Header 22", the CLD (Figure 8.26) explores loss impact analysis and the investigation concepts and shows the variables that influence risk management in recovery projects. One of the main highlights of the discussion is the importance of loss-impact analysis stage after the disaster to evaluate and assess the damage. It has been mentioned by several participants that due to time and money constraints and emergency work, a proper detailed investigation was a huge challenge in recovery projects. This negatively influences the quality of the recovery project and increase rework.

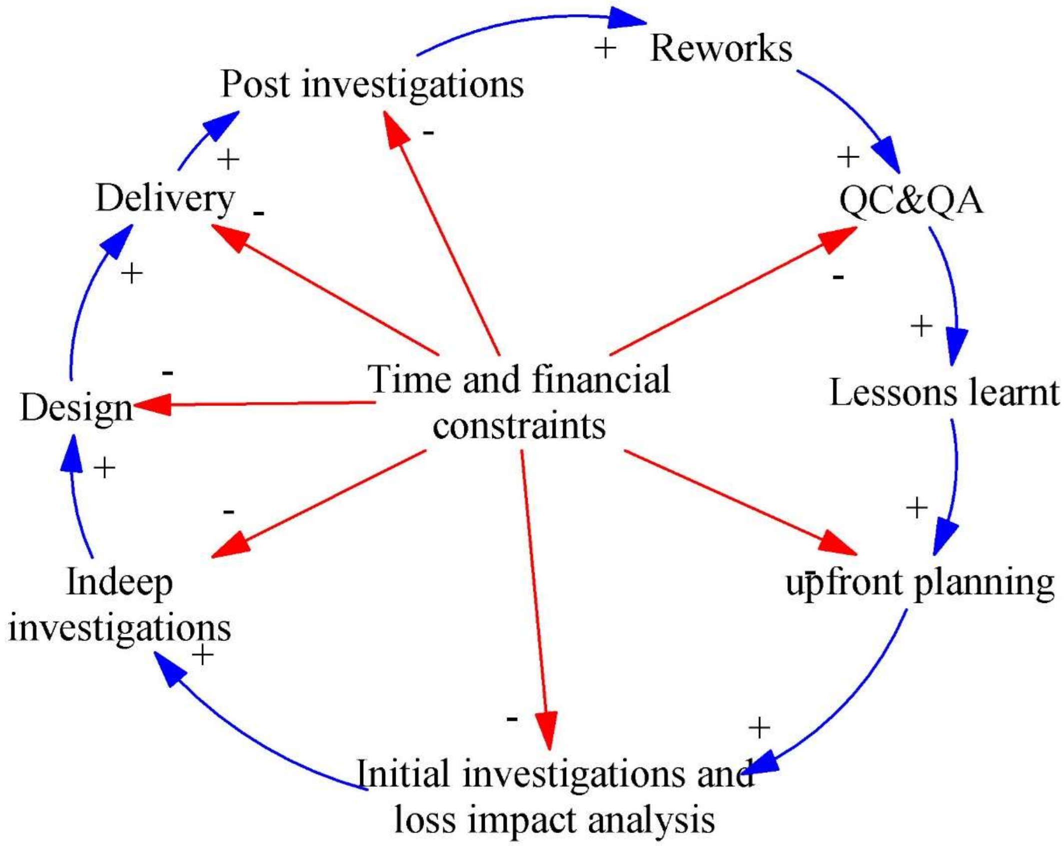


Figure 8.26: CLD of investigations.

8.3.23 Productivity

Based on the participants' responses in "Appendix E, Header 23", productivity was identified as an important concept that influence risk management in recovery projects. Figure 8.27 represents CLD of productivity in recovery projects.

Participants believed that productivity is highly linked to risk management in recovery projects. Some risk in the risk register could slow work down. In addition, there are always risks associated with increased productivity. Time is becoming more critical in recovery projects because people need to get back to normal ASAP, which could affect the quality, cost and productivity. Nevertheless, participants declared that the main problem with productivity is around planning. Insufficient planning increases the risks and losses and reduces productivity. Therefore, it was clear that productivity in recovery projects is influenced by planning, complexity, number of risks, quality and cost.

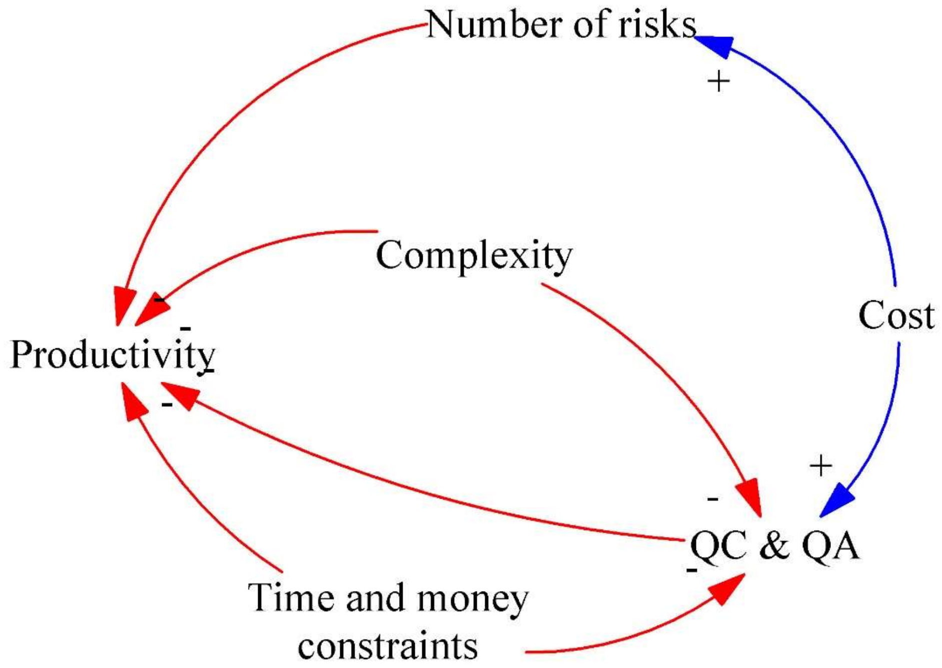


Figure 8.27: CLD of productivity.

8.3.24 Temporary work and traffic management

Based on participants' responses in "Appendix E, Header 24", temporary work and traffic management were identified as critical concepts that influence risk management in recovery projects. Figure 8.28 represents CLD of temporary work and traffic management in recovery projects.

Participants illustrated that recovery projects include more temporary work to support the buildings and the work after a disaster than traditional projects. Also, managing the traffic is a huge challenge in recovery projects due to public safety concerns. Also, due to the continuity of related disaster risks, like aftershocks for earthquakes, the temporary works and traffic management are gaining much attention in recovery projects supported by the high prioritisation of safety and health risks.

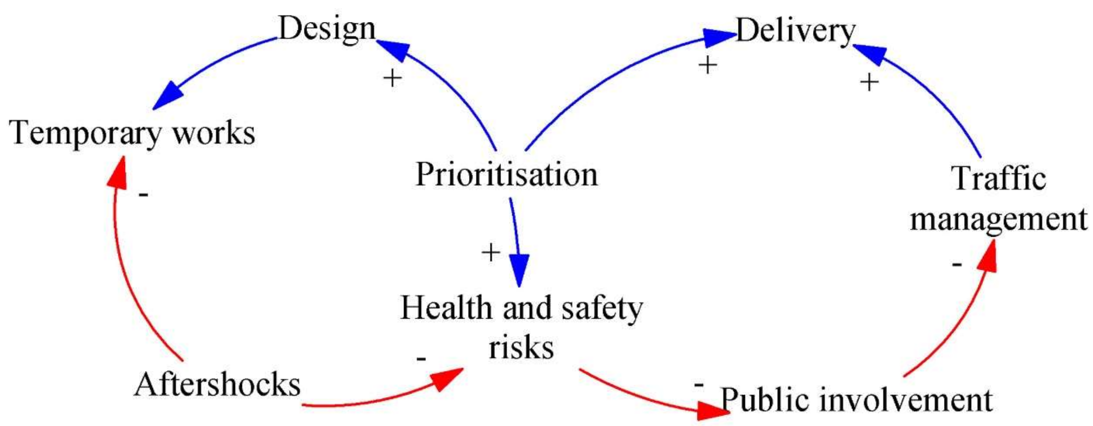


Figure 8.28: CLD of temporary works and traffic management.

8.3.25 Number of Requests for Information (RFIs) and Work Scope Changes (WSCs)

The following section discusses the influence of the number of RFIs and WSCs in the risk management in recovery projects based on the participant responses in "Appendix E, Header 25". Due to the apparent link between RFIs and WSCs, a combined CLD has been generated for the variables that influence both. Figure 8.29 represents the CLD of RFIs and WSCs in recovery projects.

Participants believed that the high number of WSCs and RFIs are expected in recovery projects due to the unclear scope. Some participants believed that projects with many WSCs are expected to perform less than others with fewer WSCs. Therefore, it is important to give attention to define the scope of work as much as possible for better cost control. This would increase the focus of the delivery teams to deliver the project and save time and money for producing WSCs.

Participants in "Appendix E, Header 25" linked the number of RFIs and WSCs to the risk profile. The more the RFIs and WSCs in a project, the riskier the project is. With a clear scope, risks would be less in a recovery project. One of the main risks is the uncertainty of the design which produced huge number of RFIs and WSCs. Directly after a disaster, you are dealing with unknown geography and unknown services. Some designs are done in a hurry. Some of these designs could be acceptable before a disaster but may not be fit for purpose or cannot be applied after the disaster. The more defined scope of work in a recovery project, the lower the deviation from TOC and the better the performance would be.

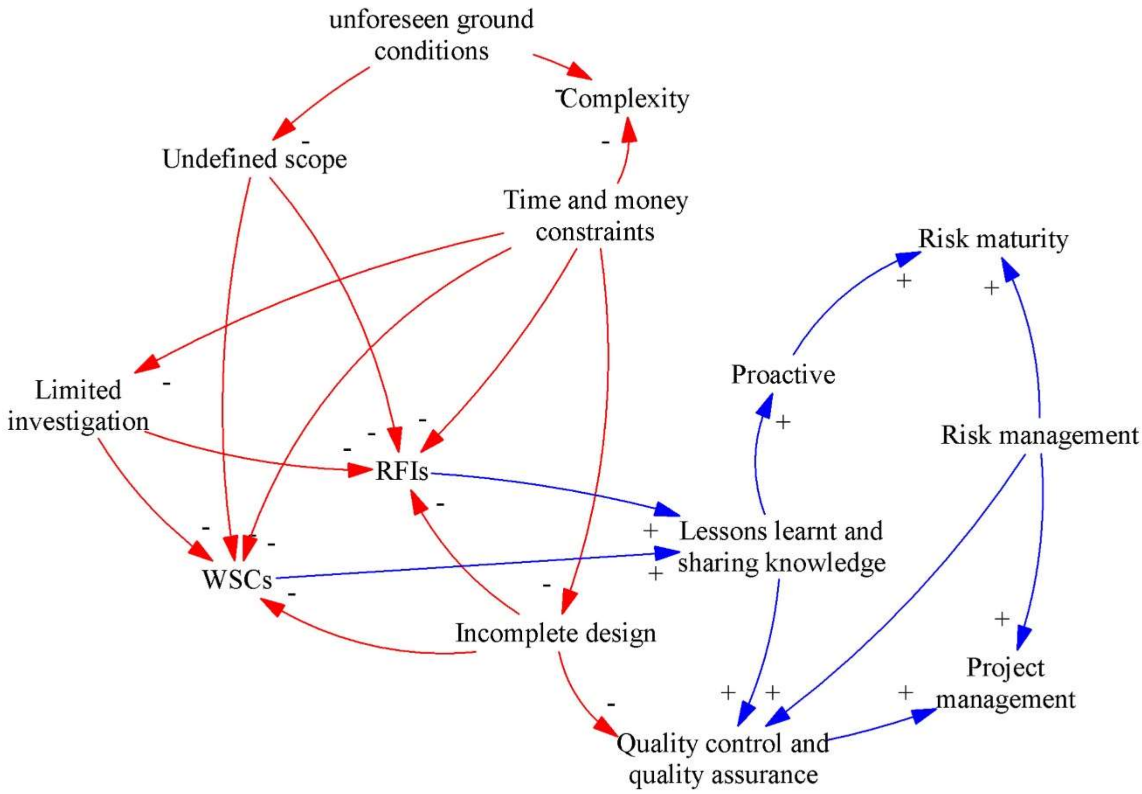


Figure 8.29: CLD of RFIs and WSCs in recovery projects.

8.3.26 Lessons learnt

Figure 8.30 shows the CLD of lessons learnt in recovery projects, and the variables that influence risk management from the participant's point of view as per "Appendix E, Header 26". Based on participants responses, SCIRT was a great case for lessons learnt as a post-disaster recovery system. Some of the lessons learnt are that the recovery systems seem to be complex and dynamic, with continues changes. post-disaster recovery system required the following; combinations of integrated effort from all parties involved, leadership that promotes smarter processes with feedback loop abilities to learn from early projects, smarter information systems and document controls, innovation, effective communication, collaboration, training to add values and to deliver the desired outcomes.

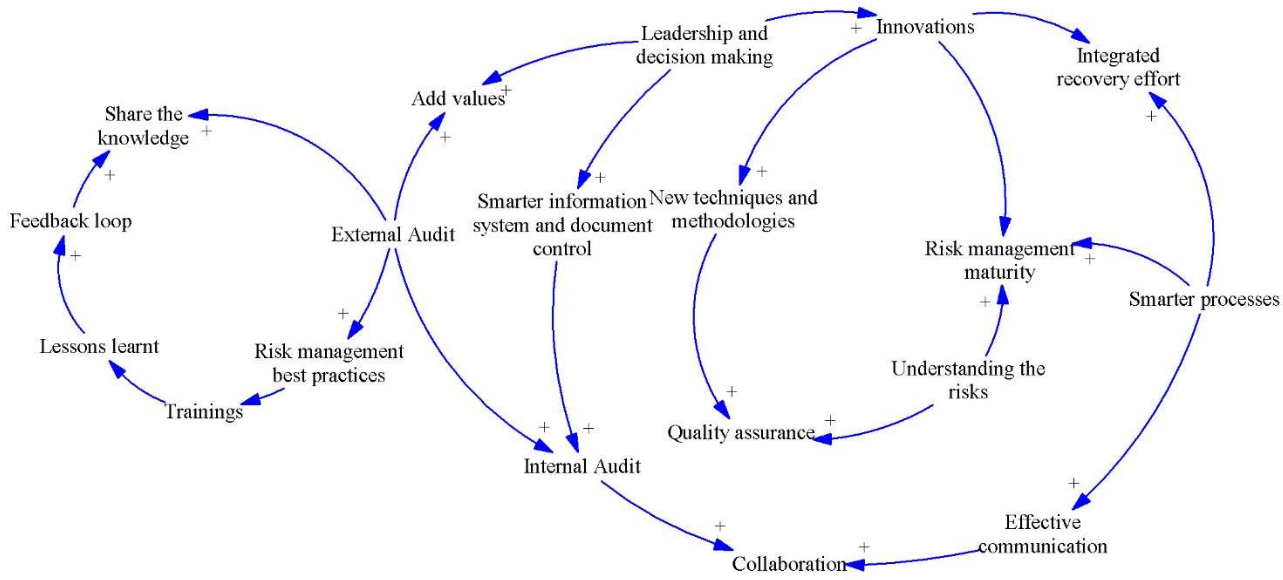


Figure 8.30: CLD of lessons learnt.

8.4 Model development

8.4.1 Smarter post-disaster risk management approach

As a reflection from the participants' responses in "Appendix E, Header 26", there was a trend of requesting smarter ways of managing risks in the recovery project. The term smart and critical thinking have been mentioned over 13 times from 6 different participants in related to risk management. This trend was the base of creating the term smarter post-disaster risk management in this research. Table 8.2 summarised the characteristics of the smarter PDRM approach based on the participants' responses in "Appendix E, Header 26". These characteristics contributed to shaping the principles of the PDRM model in this research.

Table 8.2: Characteristics of the smarter post-disaster risk management approach.

Participant's ID	**Characteristics**
Participants P6, P11, P18, P20 &P21	Smarter procurement strategy of one umbrella and a single identity. It should be an overhead competitive alliance that merges and drives the culture and early risk awareness for more effective PDRM.
Participants P13 & P26	Highlighted the importance of the leadership with critical thinking skills, honest and fair trade to change and drive the culture of effective risk management inside post-disaster recovery systems.
Participants P12 &P20	The risk management approach should be flexible in accepting the different cultures of stakeholders and promoting a positive attitude towards achieving the recovery goals.
Participants P9, P11, P17, P20 & P21	The risk management approach should be proactive and upfront about risks. This must be driven by an effective prioritisation strategy.
Participants P2, P14, P21& P23	Must contain lessons learnt and a feedback loop with early assessment from early projects in the same programme.
Participants P18, P19, P21, &P26	Must include intelligent risk management systems and procedures which are scalable and fast-track.

8.4.2 The Causal Loop Diagram of the model

After extracting all the concepts that influence the risk management in the recovery system and developing the individual CLDs using NVivo and Vensim software, the final CLD of the PDRM model was created. The CLD of PDRM model is a combination of the individual CLDs that have been discussed previously in the above sections. As it could be seen in Figure 8.31, the model used the ISO31000 process as the core of the model seeking more integrated risk management in the recovery systems using SCIRT as a case study.

To simplify the findings of PDRM model, the following table summarises the model concepts and the key attributes.

Table 8.4: PDRM-model's Concepts and Key Attributes

Number	**Concepts in recovery projects**	**Key Attributes**
1	***Establish context***	• Establish context in recovery projects required pre-disaster planning of post-disaster risks. • Establish context should be event focused. • Good intentionality of all parties to deliver the programme and help the city recover from the disaster and overcome the public and political involvement challenge. • Clearer organisational and PDRM objectives. • Good risk management leadership that endorses quick decision making. • A strong shift in culture toward effective PDRM. • Good procurement strategy with integrated information and project management systems.
2	***Risk assessment***	• There is a broader and more significant scale of work involved, which requires integration between all levels. • The emergency work drives the risk assessment. • Fast track procedures and risk prioritisation for quick response are essential. • High challenges of having different working environments and different risk profiles.

Number	**Concepts in recovery projects**	**Key Attributes**
		• Risks are hard to be quantified due to the unclear scope and unforeseen events. • There is a need for better understanding of the risks and the emotional involvement associated with the recovery programme, such as high-stress levels. • The importance of having lessons learned from previous projects in the same programme, and the feedback loop to share the knowledge and avoid delays.
3	***Risk treatment***	• Critical thinking to change the culture and the mentality of the team is essential for better cost control and more effective risk treatment. • The evaluation procedure endorses a proactive approach where lessons learnt from early projects in the same programme, and feedback loop and knowledge sharing between all parties is highly recommended. • Risk treatment requires an understanding of the staff capabilities and human factors for better decision making.
4	***Monitoring and reviewing***	• A combination of external and internal audit approaches to risk management in recovery projects is highly recommended. External audits provide new ideas, sharing the knowledge and endorse new staff to apply the right risk-management procedures while the

Number	**Concepts in recovery projects**	**Key Attributes**
		internal audit is saving time and money. To combine the benefits, moving along in the recovery programme, the external audit frequency should be decreased and should be replaced with internal audit to avoid time delays and cost increase.
5	***Communications***	• Clear communications about intentionality to meet people's expectations taking into consideration the irritation, the emotional involvement of the people. • Broader and more complex due to the considerable number and the variety of the stakeholders involved. • Due to the time and money constraints in recovery projects, the communications need to be faster by cutting the regular consultation process and the front head communication to avoid any conflict or frustration. • There is a need for aftershock communications. • Communications in the recovery project need to take into consideration the language barriers generated due to different backgrounds and the variety of cultures of the new staff.
6	***Resources in recovery projects***	• It is influenced by emotional and human factors that are related to the disaster situation. • Lack of resources is a common theme after the disaster.

Number	Concepts in recovery projects	Key Attributes
		• High risk of having inexperienced staff who are working under pressure could increase human error, which affects the quality and increases the risk profile. Training programs are essential in recovery projects. • Resource prioritisation is critical. • Measure team capabilities and staff welling programs in recovery projects to avoid staff retention and achieve the programme objectives.
7	***Culture shift in recovery project***	• Focus on shifting the culture of staff towards better awareness of event-driven risks. • There is an expected overlap between different layers of culture in recovery projects, including business culture, company culture, and public culture. • Expected resistance from the staff, which requires enough flexibility to manage their mixed culture.
8	***Building trust in recovery projects***	• There are different dimensions of trust, which need to be considered in recovery projects, including the trust between management levels, public trust, and the trust in the team and staff. These all require a strategic trust plan to avoid any frustrations or delays to the recovery programme. • The trust between the client and the delivery teams should be eased by developing a contractual

Number	**Concepts in recovery projects**	**Key Attributes**
		competitive alliance model that catches the attention of the delivery team with no high risk. • Increasing the public trust by honest and effective communication, taking into consideration the emotional dimension of the situation. • Building the trust inside the team by considering their wellbeing, human factors, their concerns regarding future work, and the development of their culture towards risk awareness.
9	***The complexity in recovery projects***	• Recovery projects are considered significant and critical with time and money constraints, which require more critical thinking and complicated procedures. • There are lots of external involvement from different parties, including a large number of public and private stakeholders, such as governmental organisations, politicians, public, third-party insurances and media. • Recovery projects are dynamic with continuous changes, such as in regulations, standards which lead to continuous design changes. • The recovery projects are steered by prioritisation, which could change the risk appetite for the recovery organisation anytime.

Number	**Concepts in recovery projects**	**Key Attributes**
		• There are different dimensions of emotional and social impacts that may have national influence.
10	***The public involvement and emotional intelligence***	• A huge range of public engagement with high emotional and sensitive psychology, which require emotional intelligence from recovery organisations. • The public involvement is deep, to the degree that they could be described as residential clients, as most of the recovery work is under their sights, and their supervision because the working environment contains them, and recovery organisations are accountable for their safety.
11	***Different market after a disaster***	• The disaster has changed the environment, which has generated a unique situation. • New opportunities arise; which encouraged so companies to shift their business core to construction with limited experience in the industry, which affect the quality of the deliverables. • The competition in the market seems to be less, as the volume of work has been huge after the disaster. • Enhanced procurement and recurring programs to test the suppliers and staff capabilities are essential to avoid or reduce the risk of poor quality due to lack of experience.

Number	**Concepts in recovery projects**	**Key Attributes**
12	***The risks profile in recovery projects***	• More event related risks, and it depends on the type of disaster. • Risk profile in recovery project appears to have a high level of emotional and social impact with wider exposure, which could affect the recovery organisations' reputations. • Risk profile requires more proactive communication approach. • The uncertainty levels are high because of undefined scope, and unforeseen, such as ground conditions after the earthquake, which require better investigations.
13	***RMM***	• Leadership plays an essential part in that due to the responsibility of increasing the post-disaster risk awareness and endorsing the risk management procedures. • RMM is increased with a better understanding of the surroundings, which is a key to surpass the time and money constraints in recovery projects. • Internal and external audits, which include a clear lesson learnt or a feedback loop, is key to improve the RMM in recovery projects.

Number	**Concepts in recovery projects**	**Key Attributes**
		• Strong document controls and intelligent information systems positively influence the RMM in recovery projects. • It would be recommended to have numerical RMM measures or KPIs, which could drive the risk management performance.
14	***Quality Controls (QC) and Quality Assurance (QA)***	• QC and QA in recovery projects are highly influenced by trust, culture, internal audit, lack of resources, time and money constraints. • A self-quality performance approach is meant to be the preferred option in recovery projects due to time and money constraints. • With the lack of experienced staff and less training, the quality appears to be affected, and lots of rework is expected. • More investigations with enough training for the staff incorporating lessons learnt, frequent external audits, besides a robust internal auditing procedures could be the solution for better quality outcomes in recovery projects.
15	***Mixed centralised and decentralised***	• The combined benefits of having centralised governance controlling the risk procedures direct the people toward effective risk management and best

Number	**Concepts in recovery projects**	**Key Attributes**
	Risk management approach	practices, and decentralised collection of ideas, sharing the knowledge and the skills to deal with the on-site risks seems to be the key strategy that could endorse quick decision making and avoid delays in recovery projects.
16	***Prioritisation strategy***	• Due to the emergency and the limited time in post-disaster, there is a need for a prioritisation strategy to cover work, resources, and risks.
17	***Undefined scope of work and uncertainty levels***	• Time limitations and emergency work increases the uncertainty in the recovery project. • Limited investigations, especially at the beginning of the programme, increase the uncertainty. • The human situation created a unique programme where the recovery organisation was forced to do the work concurrently and even start some projects without enough investigation or clear scope of work. • Considering the above points and building the front risk mitigation strategy to solve these outstanding issues is vital.
18	***The interactions and conflict of interest in recovery projects***	• Interactions in recovery projects are complex as it happened across and between different layers and dimensions, such as the interaction between different sectors as public and private sectors, interactions of workload between delivery teams working in the same

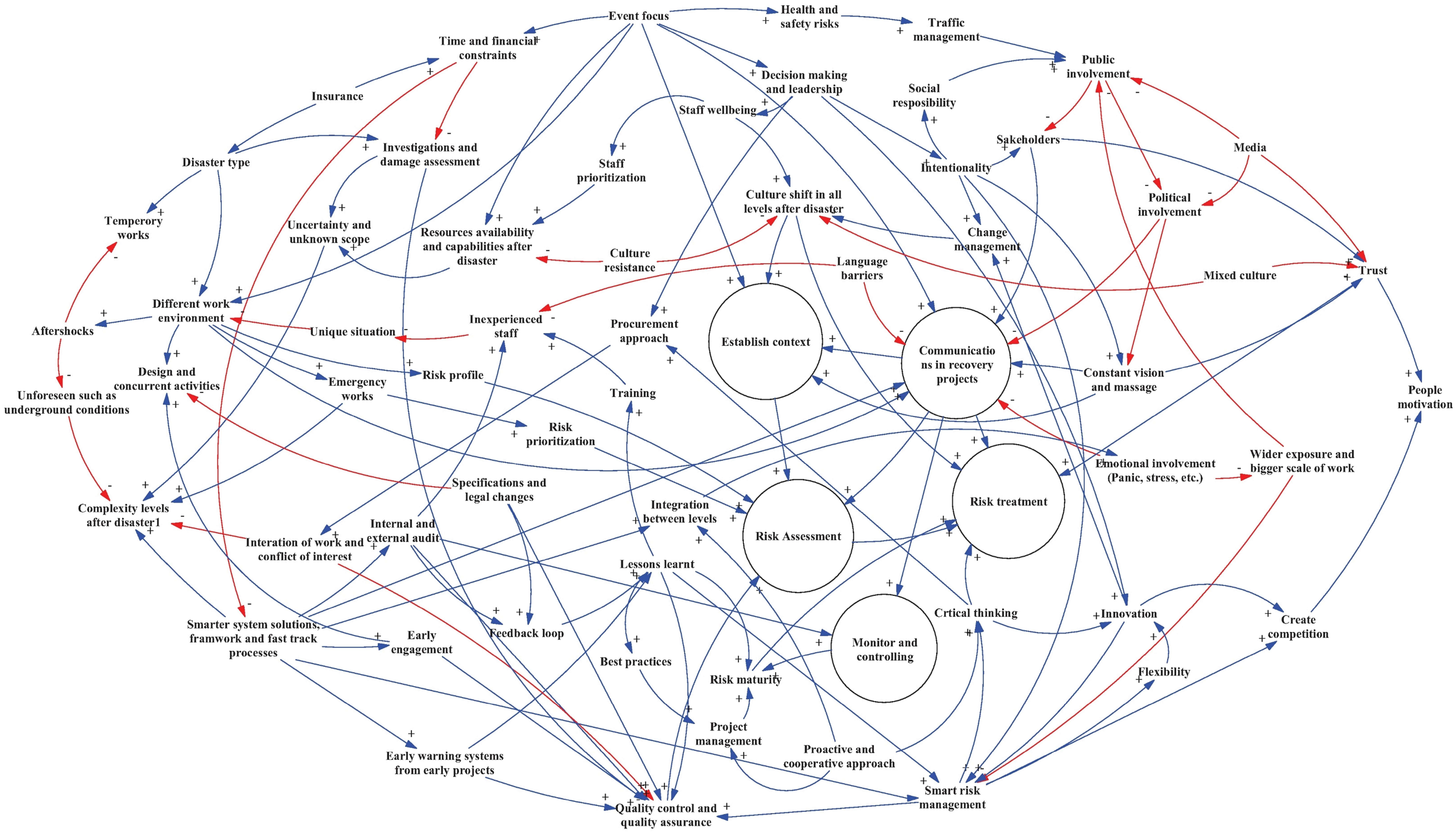
Number	**Concepts in recovery projects**	**Key Attributes**
		area inside the same programme and even with external organisations, and interactions between project phases. • This complex interaction requires a high level of cooperation and smarter systems and procedures in place, which is flexible enough to avoid any conflict and ease the friction in between all these layers. • In addition, it required aligning the culture of all the parties to endorse better cooperation and direct the effort to the desired outcomes.
19	***Changing and dynamic environment***	• The recovery-working environment is so dynamic that changes are expected all over the recovery system, such as standards updates, regulations updates, and process updates. • The dynamic recovery systems require effective communication strategies and culture shift to endorse the adorability and adoption of changes. • In addition, it requires smarter procedures and effective training programs for new and inexperienced staff to enable delivery that is more effective.
20	***Leadership and decision making***	Effective leadership in recovery projects required. • Front strategic planning skills and quick decision-making abilities.

Number	**Concepts in recovery projects**	**Key Attributes**
		• The ability to build up a teamwork environment from the right people with the right skills. • The achievement of the desired goals and objectives • It is positively influenced by choosing the right intelligent systems • Developing fast track procedures • Endorsing innovation ideas that could save time and money in the recovery programme • Listen to the market needs after the disaster
21	***Disaster and projects types***	• There appears to be a link between the complexity of the project to the number of risks and risk management performance. • The combination of the impact of the disaster on the environment and what that means to operate with that environment is essential.
22	***Loss impact analysis and investigations***	• Due to time and money constraints and emergency work, a proper detailed investigation is a huge challenge in recovery projects.
23	***Productivity***	• Productivity in recovery projects is influenced by prioritisation, public involvement, inexperienced staff, and complexity, the number of risks, quality requirements, and budget.

Number	**Concepts in recovery projects**	**Key Attributes**
24	***Temporary work and traffic management***	• High public involvement, the continuity of related disaster risks, like aftershocks for earthquakes, and the high prioritisation of safety and health risks promote the need for high temporary work and traffic management scope in recovery projects.
25	***WSCs and RFIs***	• The high number of WSCs and RFIs are expected in recovery projects due to the unclear scope, and there seemed to be good indicators of high-risk profiles. • The projects with a large number of WSCs have the worst overall performance rather than low. • It is important to pay attention to the more defined scope of work for better cost control, which will increase the focus on how to deliver the programme not how to produce more WSCs.
26	***Lessons learnt***	• The recovery systems appeared to be complex and dynamic, which required integration and cooperation between all parties. • Recovery systems required smarter procurement strategy of one umbrella and a single identity based on honest and fair trade. • Recovery systems required a proactive attitude in all management levels to gain lessons learnt from early

Number	Concepts in recovery projects	Key Attributes
		warnings to prevent similar risks of things happening again, which is endorsed by critical thinking. • Recovery projects required effective leadership that promotes smarter processes with feedback loop abilities to learn from early projects. • Recovery systems required smarter information systems and document controls to endorse collaboration and sharing knowledge between parties. • Training and upskilling programs are essential even it could consume some time to drive culture shift for more PDRM awareness. • Innovations and thinking outside the box to use new technologies to save time and money.

Figure 8.31: CLD of the PDRM model.



8.4.3 The principles of the model

Based on the participant's inputs using NVivo analysis and the outcomes from AHP, QCA and STMs, it was clear that post-disaster recovery systems are unique and complex and that it needs more effective ways to deal with the risk management. Ten principles have been identified as pillars of the PDRM model based on the CSFs outcomes, Chapter 7 and Header 27 in Appendix E.

Figure 8.32 illustrates these principles.

Figure 8.32: Principles of PDRM model.

This PDRM model is based on Intelligent Risk Management Information Systems and Procedures (IRMISP) and a pro-active attitude to gain lessons learning from early projects to prevent similar risks happening again, which is endorsed by critical thinking. In addition, it is supported by an effective procurement strategy of one umbrella to lead and motivate the delivery teams with fairness and honesty and be the core of establishing a more stable working environment after a disaster. Also, to communicate quickly with a clear, structured message to avoid any conflict in this highly emotional environment. Nevertheless, controlling the culture shift and being flexible enough to drive a positive attitude towards effective PDRM.

8.4.4 Holistic view of the model

To reveal the essentials and visualise a bigger picture of the risk management inside recovery systems, textual analysis of the participant's inputs has been conducted using Word Cloud feature in NVivo (Figure 8.33). The Word Cloud feature identifies words that frequently appear in the interviews, the more frequently the word appears; the larger the word is shown in the cloud.

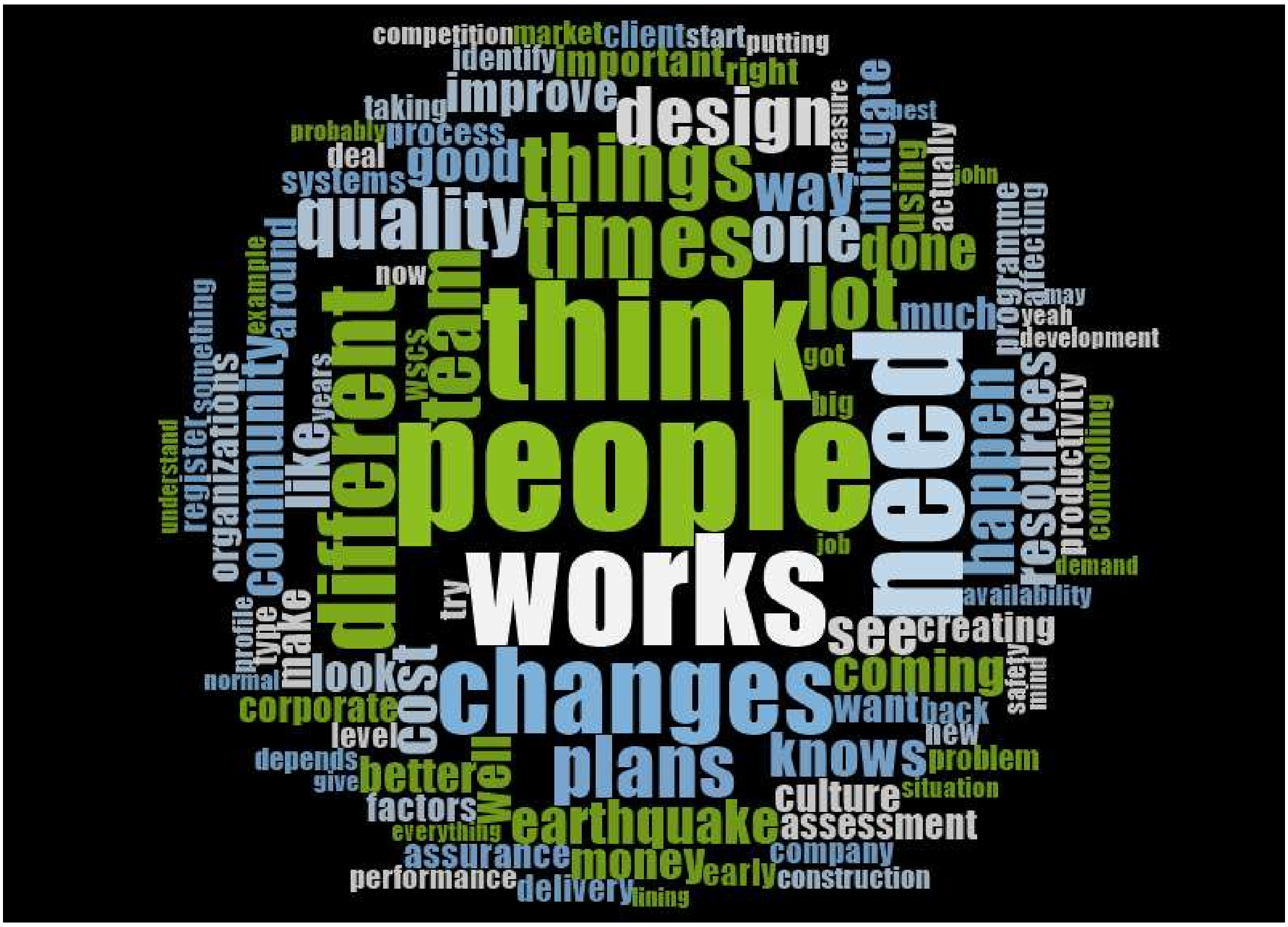


Figure 8.33: Word cloud from the participant's interviews.

Here follows a further investigation of words using Word Tree analysis in NVivio. The word "different", with its stemmed words, has appeared with high frequency attached to specific words, as shown in Table 8.5. These words are risk management, work, people, culture, environment, and thinking.

Table 8.5: The frequency of the word “Different” in the interview participants transcript

Different	Risks/risk management (19 times)
	Work (13 times)
	People (11 times)
	Culture (11 times)
	Environment (9 times)
	Thinking (5 times)

Figure 8.34 shows a bubble chart of the words attached to the word “different”. It appears that interview participants’ have recognised the differences in thinking, environment, culture, people, works, risks and risk management after a disaster compared to BAU.

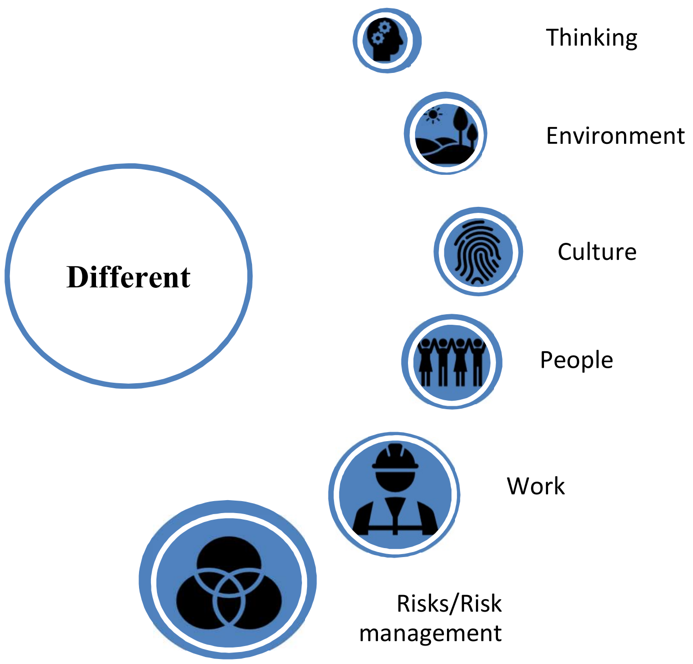


Figure 8.34: Bubble chart showing the frequency of the words attached to “different”.

Moreover, if we looked at “need” word, with its stemmed words, it has appeared with high frequency attached to specific words, as shown in Table 8.6. The words give a skim of what is required and caught the attention in the post-disaster recovery systems.

Table 8.6: The frequency of the word "need" in the interview participants transcript

Need	Get it done (17 times)
	Risk management (14 times)
	Resources (12 times)
	Better communication (11 times)
	Processes in place (8 times)
	Better understanding (6 times)
	Investigations and assessment (6)
	Value for money (6)
	Changes (5 times)
	Commitment (5 times)
	External audit (5 times)
	Internal audit (4 times)
	Planning (4 times)
	Time (4 times)
	Technology (3 times)
	Effort (3 times)
	Think smart (3 times)
	Innovation (2 times)
	Meet expectations (2 times)
	Support (2 times)
	Flexibility (2 times)

The words with the highest frequency attached to "need" is "get it done" with 17 times. Which explains the pressure on recovery systems to deliver, rebuild and show the result on the ground. Secondly, with 14 times is risk management, it is showing the awareness from participant to the need for practical risk management that cope with the risk dynamics in post-disaster recovery systems. Resources came next to show the challenge of available resources such as funding, staff, materials, etc. in post-disaster recovery systems. In addition, the interview participants realised the importance of better communication, processes in place, enough investigation for better understanding of the current situation to be able to offer value for money solutions and effective PDRM. Commitment and putting the effort from all the parties involved in post-disaster recovery systems were also highlighted as a requirement. Also, external and internal audit, using technology, thinking smarter, listen to innovations, support the team, and give enough flexibility to different culture involved in the recovery programme were all highlighted as requirements for effective PDRM.

If we combined the analysis of both words, “different” and “need”, it gives us a holistic perspective that since the environment, the people and the work, and everything changes after a disaster; a different approach towards critical thinking is required for more effective PDRM.

Nevertheless, as a reflection from the participants’ engagement, there was a consistent focus towards smarter ways of doing things in recovery projects for more effective PDRM, which also was highlighted in a lessons-learnt note. The word “smart” in the discussion was attached to several areas as below,

- Smarter procurement strategy where the recovery alliance based on a competitive strategy even though it is under single identity such as SCIRT and the pain/gain competitive model which encourage the delivery teams to work harder to increase their shares while helping in recovery.
- Smarter ways of risk identification and risk treatment using prioritisation and critical thinking and lessons learnt.
- Using technology solutions for more effective risk management, which highlighted the need for IRMISP.
- Smarter construction methodologies by listening and supporting innovations to reduce risks and for better outcomes.
- Using emotion intelligence when dealing with public and programme team due to the high level of emotions involved and the public and media high engagement.

In addition, the disaster created a unique environment, which considered being new to even the experts. This highlighted the importance that the recovery organisations consider training programs to upskill the staff in specific aspects as emotional intelligence, quality control and quality assurance, and safety and environment to cope with this new situation and achieve the desired outcomes.

8.4.5 Practical application of the PDRM model

The risk management within recovery projects is very dynamic due to the fast track lifecycle of the response so people back to their normal life. The life cycle of the recovery consists of actions in the following order; emergency response, initial recovery, short-term recovery, long-term recovery and finally restoration to the normal routine (BAU). Nevertheless, the emotional involvement plays a critical role in shaping the disaster response at all levels. For better understanding where the PDRM model fits in the disaster timeframe, Figure 8.35 shows the correlation between the phases of response to a disaster over time and the emotional position of different types of risk management models.

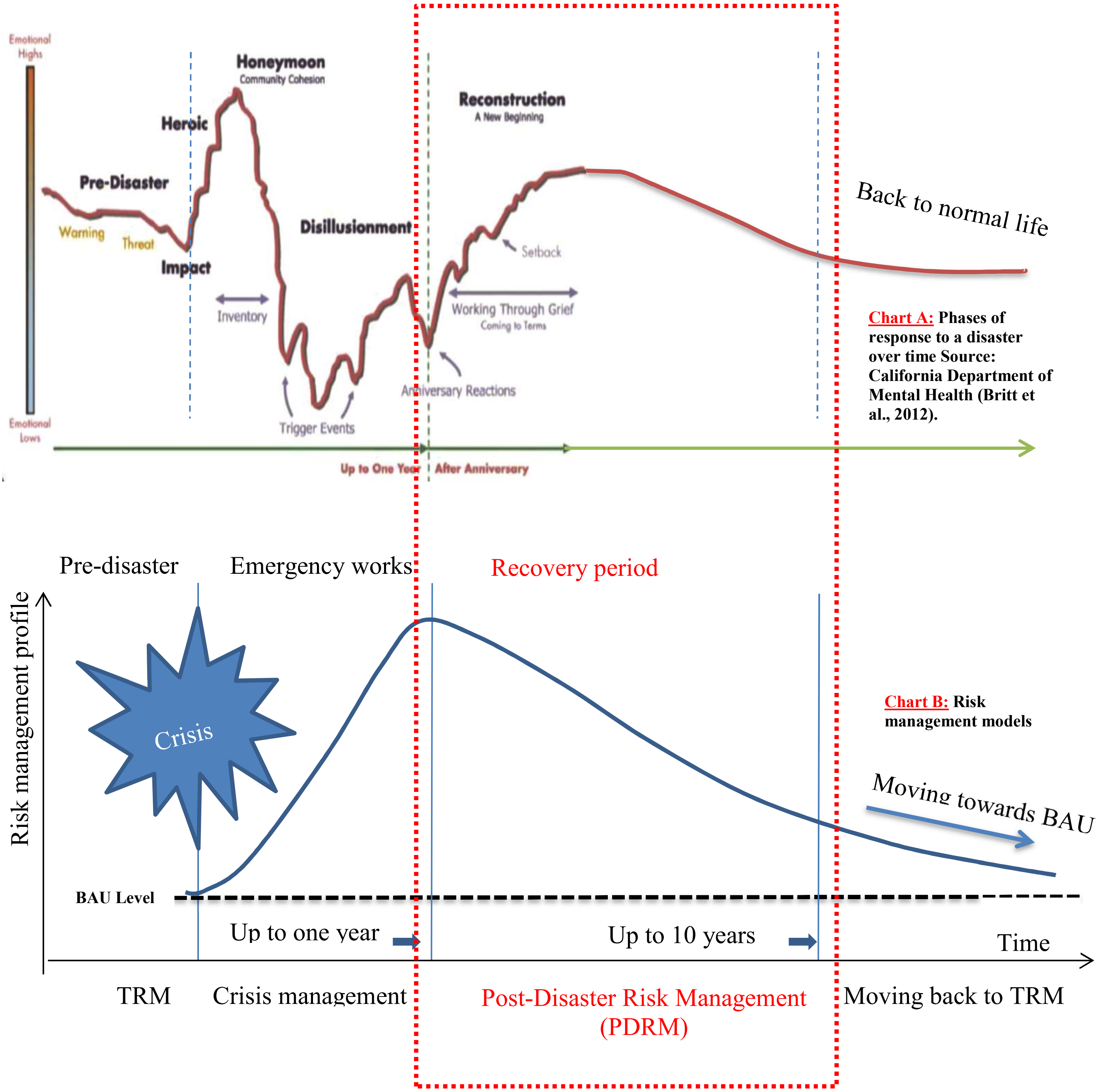


Figure 8.35: Positioning of the PDRM model

As it could be seen from the Californian department of mental health diagram (Chart A), the emotional levels during the disaster life cycle vary frequently. The peak or “Honeymoon” appears to be in the inventory period directly after the impact. The emotion levels then settle down until the trigger events; such as aftershocks in earthquake disasters; come along where the emotions pick up the momentum again. This period is the emergency work-period (Chart B) where crisis risk management is the model to follow. After the disaster anniversary and moving along to the new beginning period where the recovery and reconstruction begins, the emotional level starts to get into its second highest peak. This period is the recovery period, where the PDRM model is fit. This period depends on the type and the volume of the disaster but normally it is up to 10 years from the recovery (Britt et al., 2012), after this period, the market starts to go back to BAU situation and the TRM model.

8.5 Discussion

In this section, the outcomes of the PDRM model will be discussed related to the ISO31000 and the other literature reviews. There are some of the PDRM model outcomes coincide with the existing ISO31000 and literature reviews, and some outcomes are new to the research market. Table 8.7 shows the relation between the ISO31000:2018 risk management principles, and PDRM-model’s principles.

Table 8.7: ISO31000:2018 risk management Principles Vs. PDRM-model's Principles

ISO31000:2018 Risk Management Principles	**PDRM-model's Principles**	**Similarity Degree**
Integrated		Used as investigation approach based on ST&SD
Structured and comprehensive	Effective procurement strategy based on fairness and honesty	Partial
Customised	Establishing a more stable working environment and building Trust	Partial
Inclusive	Critical thinking and prioritisation	Partial
Dynamic	Lessons Learnt with Audit and Proactive Behaviour	Partial
Best available information	IRMISP	Partial
Human and cultural factors	Culture shift and flexibility	Partial
	Emotional intelligence	Customised
	Upskilling and Training	Customised
	Effective leadership to promote innovation and motivation	Customised
	Quick and clear communication with consistent messaging	Customised

The ISO31000:2018 risk management Principles are more generic, however, the PDRM-model's principles are customised and specific to the post-disaster recovery system. Most of the principles could fall under the three integrated, inclusive and customised principles of ISO31000:2018. According to ISO31000:2018, these principles help organisations to modify their risk management to fit their needs and objectives. Customised risk management system which brings risk management to the centre of decision making and which supports all activities across the organisation. However, in recovery projects, there is no luxury of time to develop customised risk. Therefore, it is important to be ready with a model that can be used in such a situation. PDRM model is a customised guideline which aimed to help post-disaster recovery systems understand and address the different uncertainties which will unavoidably appear in their path to achieving their objectives.

On the other hand, Chapter 2 in this study represented a scan of what the previous studies and literature review had covered in PDRM. It has been noted that there were no studies found investigating the difference between the risk management before, during and after a disaster in construction. However, there were common principles that coincide with the previous studies in the risk management market, such as the importance of leadership, training and communications. However, the PDRM model has added customised principles to post-disaster recovery systems. These customised principles are as follows,

- The emotional intelligence principle which covers the heavy emotional involvement and the high-stress levels associated with post-disaster recovery systems scope of work.
- IRMISP principle, which is a customised risk management information system that should be set up for more effective risk management in the post-disaster recovery systems. It is essential to break the complexity of work and the unforeseen risks in post-disaster recovery systems.
- The research provides a CLD of PDRM model that can be used in the risk management workshops as a core to identify and manage risks in recovery projects.
- Lessons Learnt with audit and feedback loop principle, which is essential to mitigate any delays and fall in the same mistake again in the same programme.
- Even the culture concept has been mentioned in previous studies as an important part in risk management; it was identified as a crucial principle to do culture shift towards more effective risk management due to the mixed culture and the different background of resources in the recovery project.
- Effective communication is an essential concept in many studies on risk management. However, in PDRM, communication has additional important dimensions associated with it. For example, building the trust between stakeholders and promoting the right intentionality of helping the people and the community to recover from a disaster.

8.6 Summary

In this chapter, SD modelling has been used to develop the PDRM model. Raw data from semi-structured interviews with 20 construction professionals in SCIRT was the core of investigation based on GTA. This is in conjunction with the outcomes from AHP, QCA and STMs represented in the previous chapters. The goal of this approach was to look in details at the concepts and the attributes that influence the risk management in recovery systems and visualised it in a CLD.

The SD modelling methodology was divided into two stages, the coding process using NVivo 11 software, and the model development using CLD software Vensim. The coding process included identifying the concepts in the collected data (open coding), disaggregating the concepts into attributes (axial coding), identifying the causal relationships between the concepts and attributes, and picture these relationships in words-and-arrow diagrams. This procedure has been followed to develop individual CLDs for each concept. Finally, a combined CLD was created to represent the final PDRM model.

The PDRM model is based on 10 principles and 26 concepts with its attributes. The principles of this model are emotional intelligence, building trust, culture shift and flexibility, upskilling and training, quick and clear communication with consistent message, fairness and honesty, effective leadership to promote innovation and motivation, intelligent risk management information systems and procedures, lessons learnt and proactive behaviour, and critical thinking and prioritisation. Figure 8.31 visualised a full picture of concepts and the attributes that influenced the risk management in the case study and represented the CLD of the PDRM model.

In addition, the textual analysis of the raw data using word cloud technology highlighted that the differentiation of environment, work and people after the disaster required a different way of thinking and promoted the need for an integrated PDRM. An integrated way of looking at the post-disaster recovery system as a whole and addressing all the concepts and the attributes that drive and influence this complex system. This model meant to be used for recovery projects during the reconstruction period after a disaster.

Chapter 9: Conclusions and Recommendation

9.1 Introduction

The study on Post Disaster Risk Management (PDRM) is summarised in this chapter, highlighting its achievements, main objectives, and overarching contribution. The research limitations and the potential directions for future research are also included.

9.2 An Overview of the Research

This research focused on developing an integrated Post Disaster Risk Management (PDRM) model to enable more effective risk management in recovery projects. The aim is to fulfil the requirements of more effective risk management in high-complexity recovery systems. While developing this model, this research promoted the use of system theory (ST) and system dynamics (SD) to investigate the entire recovery system as a whole, to breakdown the complexity and study the risk management in recovery projects in an integrated way by considering all the factors which influence and drive the system. It is important to clarify that the PDRM model does not take away from the importance of TRM; it is based on it and adds more customised principles and concepts to it in order to suit post-disaster recovery systems.

This research utilised a case study to investigate current risk management practices in recovery projects. This dissertation started with a background and an introduction to post-disaster recovery systems represented by SCIRT in Chapter 1. A detailed literature review (Chapter 2) highlighted the most relevant research, identified the research gaps and developed the motivations for this study. The methods used in this research has been described in Chapter 3, followed by the research validation (Chapter 4) where the research questions have been developed, and the point of research has been justified. This chapter represents the first step in ST to discover and identify opportunities and problems in current risk management methods. In Chapter 5, the critical risks inside recovery projects have been identified. In Chapter 6, the interactions and dynamics of risks between levels have been investigated. In Chapter 7, the CSFs of risk management in recovery projects have been explored. In Chapter 8, the final PDRM model has been developed using system dynamics modelling. The final PDRM model focussed on the underlying principles and concepts of the model. The principles serve as the foundations of the model, while the concepts refer to the essential features of the model.

9.3 Achievement of Research Aims and Objectives

The primary area of research was the investigation of complex recovery systems. Using ST and SD in conjunction with different analysis methods to develop a PDRM model. These analysis methods are AHP to investigate the critical risks inside the system, STMs to investigate the dynamics between these risks, and QCA to investigate the CSFs of effective PDRM inside the system.

The main aim of this research was achieved by developing an integrated risk management model that could be used to make up for the shortcomings of traditional risk management approach in recovery projects. The final model is represented by a causal loop diagram (Figure 8.46), which is based on the 10 principles (Figure 8.47) and 26 concepts (Table 8.1) with their attributes. Through the development of this model, several questions had to be answered.

The first question was to identify the critical risks in the different layers of management in recovery systems' "client-alliance management, and alliance execution". It was found that inexperienced staff, low management competency, poor communication, scope uncertainty, and non-alignment of the timing of strategic decisions with schedule demands, were the key risk factors in recovery projects.

Regarding the critical risk groups, it has been found that at a strategic management level, financial risks attracted the highest level of interest, as the client was looking to secure funding for the recovery projects. The clients in the particular case study were government organisations. At both alliance-management and alliance-execution levels (SCIRT and Delivery Teams respectively), the safety and environmental risks were given top priority to secure the public and environmental safety after the disaster. It is worth to mention that these types of risks associated with a high level of emotional, reputational and/or media stresses. Therefore, it is essential to consider an upfront risk management plan for the above risks for more effective risk management in recovery projects.

The second question was to investigate the interactions between risks at three levels (client, alliance-management and alliance-execution). In addition, the influence of these risks inside the system and between each other made for a better understanding of the dynamics of risk management in recovery projects. It has been found that even with the high emotion and human factors involved in the recovery projects, the financial risks for both the client and delivery teams have been one of the main concerns and drivers. After the disaster, the client realised the risks arising from a lack of resources combined with the high volume of work and the concern that the cost could go out of control alongside the funding issue with the insurance companies. This encouraged the client to create the recovery alliance model with construction organisations well-known in the market, to lock in the recovery cost. The alliance must be competitive and low risk to the recovery companies in order to attract them and build the trust that there is funding available to recover the city. This explained why the financial risks for the client and the delivery teams were connected to most of the other risk groups in the map of interactions. In addition, it was clear that the strong influence of macro risk groups at the client level on the recovery risk-management dynamics was due to the high involvement of politics, the media and the public. Moreover, the strong influence of safety-and-environmental risk groups was driven by the alliance management to secure the safety of people and restore the environment.

The third question was dedicated to determining the CSFs for effective PDRM. This study found that building trust between all parties, clearer communication and consistent messaging, established a more stable working environment. Competent and clear allocation of risk management responsibilities, cultural shift, risk prioritisation, and staff training were crucial factors. Also, QCA demonstrated a strong positive correlation of high cost performance, high schedule performance, and fewer non-conformity reports in RMM in recovery projects. Nevertheless, a good influence of few work scope changes and no incident reports have been noticed on effective risk management performance in recovery projects.

Finally, the main aim of the study was the development of the PDRM model. This model could be described as an integrated risk management model that considers how the changes which happened to the environment, the people and their work, caused them to think differently to ease the complexity of the recovery projects.

The PDRM model is based on the following 10 principles;

- Intelligent risk-management information systems and procedures that are flexible and stay on track.
- Building trust in all dimensions including clients, teams, and the public
- Ability to drive a cultural shift with enough flexibility to accept the mixed culture for more PDRM awareness
- Upskilling and training programmes
- Quick and clear communication and a consistent message about structuring

- An effective procurement strategy under a single identity, based on honest and fair trade promoting competition to deliver the desired objectives
- Good leadership to motivate and guide the recovery systems in this tough situation
- Lessons learned to prevent risks using early warnings
- Prioritisation strategy with critical thinking
- Strong emotional intelligence to face the huge emotional waves after a disaster.

In addition, the key concepts and attributes of this PDRM model could be summarised in the following points,

- Upfront planning for event-focused risks, such as the undefined scope of work and high uncertainty levels, time-and-financial constraints, resource availability, inexperienced staff, quality issues and reworks
- Effective procurement strategy with pre-disaster communications and planning
- Intentionality and commitment of all recovery parties to deliver the desired outcomes
- Good risk management leadership that endorses quick decision-making and can deliver the desired outcomes.
- Clearer organisational and PDRM objectives
- Effective risk management systems that are based on intelligent-information systems, flexible procedures, and Fast Tracking
- Post-disaster risk awareness and culture shift
- Prioritisation strategy for risks, resources, and work
- Resource capabilities and staff-wellness programmes
- A proactive risk-treatment approach where lessons learnt from earlier projects in the same programme is a must. That should be endorsed by evaluation procedure, feedback loop and sharing knowledge between all parties in the same programme.
- A quick and systematic aftershock communications procedure. Also, communications need to consider the language barriers generated due to different backgrounds and the cultures of new staff.

- The strategic plans need to reinforce trust between all stakeholders to avoid any frustrations or delays to the recovery programme. This is including the trust between management levels, the public trust, the trust inside the team and staff.
- Specific training programmes, such as emotional intelligence, QC & QA, safety and environment, as there is a high risk of having novice staff who are working under pressure. This increases human error affecting the quality and increasing the risk profile in the recovery programme. This is why training programmes are essential in recovery projects.
- Strong monitoring, review, and improvement of the PDRM practices by promoting a combination of external and internal audit approach with lessons learned and feedback capabilities.
- Consideration of RMM programmes and formalisation of key risk indicators
- Recovery projects are very dynamic, with significant interactions between different layers. They are continuously changing in terms of regulations and standards that lead to constant design changes
- Consider a high level of public involvement with high emotional-and-sensitive psychology that requires emotional intelligence and health-and-safety requirements such as traffic management and temporary works
- The self-quality performance approach is meant to be the preferred option in recovery projects due to time-and-financial constraints; however, it might increase the QC & QA risks, which is highly influenced by trust, culture, internal audit, and lack of resources
- Loss-impact analysis and enough investigations for better scope definitions are necessary. This will reduce WSCs and RFI as they are considered to have a negative influence on the PDRM performance

9.4 Theoretical and Pragmatic Contributions

The overarching contribution of this study is that it showed the benefits of using ST and SD and the potential future use of this methodology as an integrated way to investigate risk management inside complex systems. The literature review showed the gap in information on risk management in post-disaster recovery systems in particular. The study presents a comprehensive picture of the complexities that recovery systems have. It recognised that post-disaster recovery systems seemed to be complex as well as dynamic and hence, required specific PDRM model that endorses effective risk management.

Due to these complexities, this study has advanced the unexploited potential of using a combination of several theories and analysis methods in utilising the risk management inside complex systems in a theoretically informed way. The core of these theories is ST and SD to investigate the entire recovery system as a whole in conjunction with different analysis methods to endorse clearer decisions in these complex systems. The main analysis methods used in this research are AHP, QCA, and STMs. Computer software has been used, such as NVivo and Vensim software, and an online survey tool (Qualtrics). The diversity provided an integrated way of analysing and testing the recovery systems. The variety maximised the achieved outcomes and minimised the influence of unpremeditated consequences.

This study contributes towards increasing the understanding of the critical risks inside recovery projects, investigating the interaction and the dynamics of the risks between levels, exploring the CSFs of risk management, and finally, developing a PDRM model for recovery systems.

From a practical perspective, the model is a forward-planning guideline for recovery projects, especially after an earthquake, looking in detail at all the attributes and the concepts, which influence the risk management for more effective PDRM and best practices. This research could help construction professionals and decision makers to have a clearer direction for improving their risk management practices in post-disaster recovery systems. It also provides the basis to understand the critical factors influencing risk management between the different management levels and enhancing their capability towards more effective risk management. Some of the practical benefits of this model for the construction decision makers for post-disaster recovery systems are as follows:

- Use the model in the risk workshops as a base to develop a specific risk management plan for the appointed recovery system using brainstorming techniques.
- Use CLD to give an integrated picture of potential threats.
- Use the critical risks from this study in recovery-programme risk registers.
- Implement IRMISP at the start of the recovery programme that can cope with the scale of the programme and dynamics of the risks in post-disaster recovery systems.
- Implement training programs to upskill inexperienced staff.

- Implement mixed internal and external audit cycles for risk management practices in post-disaster recovery systems. Regular internal audits with short frequency, like monthly-based audits and external audits with longer frequency, such as quarterly audits for better cost efficiency.
- Use specialised communication staff with emotional intelligence skills to deal with the involvement of media and the many stakeholders.

Also, provide support to leaders who are unclear about their role. There is a need to help new people solve transitional issues, understand how to perform moving forward, facilitating progress with teams who are stuck in developing and rolling out recovery systems critical activities and projects. Problems in the implementation process need to be identified quickly and highlighted to senior management.

From the social perspective, the research highlighted some ongoing impacts of the multi-cultural environment that emerged after the disaster, including the accompanying resource issues. It also highlighted the emotional impact in the recovery programme and recommended training programmes to upskill staff in safety, environment, QA, QC, and emotional intelligence.

This study shows how post-disaster recovery systems seemed to be complex and dynamic. This is because they required combinations of integrated effort from all involved parties; leadership that promotes smarter processes with a feedback loop providing the ability to learn from earlier projects; smarter information systems and document controls; collaboration and training to add value and to deliver the desired outcomes.

9.5 Limitations of the Research

Although this research represents a justification and an in-depth investigation of risk management in recovery systems using SCIRT as a case study, some limitations can be assumed due to the nature of the data collected and its analysis. For instance, the type of disaster and the recovery project types may influence the results. Further investigations could be required for different disasters or different projects. For instance, earthquakes are different from floods, wildfires, or landslides.

Despite that AHP is known for its simplicity, justification, and efficiency as a multi-criteria decision-making process, there are limitations and concerns from precious researchers of representing the human emotions into numerical numbers. The scale in AHP could change by the change of the emotion state from one individual to another, also, the claim of human views cannot be quantified (Ahmad, Goransson, & Shahzad, 2010; Karthikeyan, Venkatesan, & Chandrasekar, 2016).

Although the investigations in this study were backed up with a rigorous literature review from around the globe, it was limited to New Zealand. The factors affecting the recovery project risk-management could be different for other location depending on its resources, government, and culture.

Nevertheless, the location of the disaster could affect the type of risks. Therefore, the model should be reviewed and adjusted accordingly to fit with the new locations, projects and different types of disasters.

These concerns may place some limitations on the practicality of the findings of this study for specific disasters and countries, but by far, it does not exclude the generalisation of the findings. Meanwhile, it does indicate that further research is recommended for different types of recovery projects and different locations.

9.6 Suggestions for Further Research

It is expected that the discussion and the investigations in this study can provide some guidance for researchers on how to approach different theories and methods such as AHP, QCA, STMs, QGT, GTA, and SD modelling for more investigations in risk management. Nevertheless, it could be beneficial in future studies to use fuzzy-set QCA to investigate the influence of the change in specific variables on the RMM inside recovery systems.

REFERENCES

Adams, F. (2008). Construction contract risk management: a study of practices in the United Kingdom. *Cost Eng, 50*(1), 22-33.

Ader, H., & Mellenbergh, G. (2008). *Advising on Research Methods: A consultant's companion* (Vols. 334-371). Huizen, the Netherlands: Johannes van Kessel Publishing.

Agarwal, R., & Virine, L. (2019). Integration Stages of Project Risk Management (PRM) into Enterprise Risk Management (ERM). *International Journal of Risk and Contingency Management (IJRCM)*, 21.

Ahmad, A., Goransson, M., & Shahzad, A. (2010). Limitations of the Analytic Hierarchy Process Technique with Respect to Geographically Distributed Stakeholders . *World Academy of Science,*, 69.

Ahrens, J., & Rudolph, P. M. (2006). The Importance of Governance in Risk Reduction and Disaster Management. *Journal of Contingencies and Crisis Management, 14*(4), 207-219.

Al-khatib, B. (2012). The Effect of Using Brainstorming Strategy in Developing Creative Problem Solving. *American International Journal of Contemporary Research, 2*(10), 29-38.

Allan, G. (2003). A critique of using grounded theory as a research method. *Electronic Journal of Business Research Methods, 2*(1), 1:10.

Allan, N., Yin, Y., & Scheepbouwer, E. (2008). *A Study into the Cyclical Perfomance of the New Zealand Construction Industry.* Christchurch: New Zealand Centre for Advanced Engineering.

Alonso, J., & Lamata, M. (2006). Consistency in the analytic hierarchy process: a new approach. *International Journal of Uncertainty, 14*(4), 445-459.

Altabbakh, H., Murray, S., Grantham, K., & Damle, S. (2013). Variations in Risk Management Models: A Comparative Study of the Space Shuttle Challenger Disaster. *Engineering Management Journal, 25*(2), 13-24.

Ammann, W. J. (2008). Developing a multi-organisational strategy for managing emergencies and disasters. *Journal of Business Continuity & Emergency Planning, 2*(4), 391-401.

Aritua, B., Smith, N. J., & Bower, D. (2009). Construction client multi-projects – A complex adaptive systems perspective. *International Journal of Project Management , 27*, 72–79.

Arklay, T. M. (2012). Queensland's state disaster management group: An all agency response to an unprecedented natural disaster. *Australian Journal of Emergency Management, 27*(3).

Aven, T. (2013). On the Meaning and Use of the Risk Appetite Concept. *Risk Analysis, 33*(3), 462-468.

Banaitiene, N., & Banaitis, A. (2012). *Risk Management in Construction Projects.* (N. Banaitiene, Ed.) Rijeka, Croatia: InTech.

Baubion, C. (2013). *OECD Risk Management: Strategic Crisis Management.* OECD Working Papers on Public Governance: OECD Publishing. Retrieved 8 2, 2015, from http://dx.doi.org/10.1787/5k41rbd1lzr7-en

Bazeley, P., & Jackson, K. (2013). *Qualitative Data Analysis with NVivo.* London: SAGE.

Bertalanffy, L. V. (1969). *General System Theory: Foundations, Development, Applications* (Revised edition ed.). George Braziller Inc.

Blockley, D. (2013). *Earthquake risk management of civil infrastructure: integrating soft and hard risks* (Vol. 9). (S. T. Goda, Ed.) University of Bristol, UK: Woodhead Publishing Limited.

Bosher, L., Dainty, A., Carrillo, P., Glass, J., & Price, A. (2007). Integrating disaster risk management into construction: a UK perspective. *Building Research and Information, 35*(2), 163-177.

Botha, P., & Scheepbouwer, E. (2015). Christchurch rebuild, New Zealand: alliancing with a difference. Proceedings of the Institution of Civil Engineers . *Management, Procurement and Law , 168*(3), 121-129.

Box, P., Thomalla, F., & Honert, R. v. (2013). Flood Risk in Australia: Whose Responsibility Is It, Anyway? *Water, 5*, 1580-1597.

Britt, E., Carter, J., Conradson, D., Scott, A., Vargo, J., & Moss, H. (2012). *Resilience framework and guidelines for practice.* Christchurch, New Zealand: Report for the Ministry of Social Development, University of Canterbury.

Brown, L., Beetham, R., Weeber, J., & Paterson, B. (1992). *Geology of the Christchurch Urban Area.* Institute of Geological and Nuclear Sciences, Lower Hutt, New Zealand: American Geological Institute.

Buerki, L. (2006). *Systemic Approach* (Seminar Series ed.). Charles Sturt University: Faculty of Commerce, School of Marketing and Management.

Cagliano, A., Grimaldi, S., & Rafele, C. (2015). Choosing project risk management techniques. A theoretical framework. *Journal of Risk Research, 18*(2), 232-248.

Campbell, D. T., & Fiske, D. W. (1959). Convergent and discriminant validation by the multitrait multimethod matrix. *Psychological Bulletin, 56*, 81-105.

Cardona, O. D., & Carreño, M. L. (2011). Updating the indicators of disaster risk and risk management for the Americas. *IDRiM Journal, 1*(1), 27-47.

Carpenter, T. D. (2007). Audit Team Brainstorming, Fraud Risk Identification, and Fraud Risk Assessment: Implications of SAS No. 99. *The Accounting Review, 82*(5), 1119-1140.

Chakrabarti, S. (2002). *Mining the Web: Discovering Knowledge from Hypertext Data, Morgan Kaufmann, San Francisco, 2002.* San Francisco: Morgan Kaufmann.

Chang, Y., Wilkinson, S., Potangaroa, R., & Seville, E. (2010). *Resources and capacity: lessons learned from post-disaster reconstruction resourcing in Indonesia, China and Australia.* Paris, France.: COBRA.

Chang, Y., Wilkinson, S., Potangaroa, R., & Seville, E. (2012). Managing resources in disaster recovery projects. *Engineering, Construction and Architectural Management*, 557-580.

Christchurch Quake Map Website. (2018). *Christchurch Quake Map*. Retrieved 5 26, 2018, from http://www.christchurchquakemap.co.nz/all

Cioaca, C. (2011). Qualitative Risk Analysis Methods in Aviation Projects. *Journal of Defense Resources Management, 2*(1), 1-8.

Cole, A. (2006). *The Influence Matrix Methodology: a technical report.* Palmerston North: New Zealand: Landcare Research.

COSO. (2017). *COSO Enterprise Risk Management - Integrating with Strategy and Performance.* The American Institute of CPAs (AICPA). Retrieved from https://www.coso.org/Pages/default.aspx

Counter Disaster Unit, NSW. (2011, 3 18). *Disaster Risk Management Guidelines.* Retrieved 12 5, 2015, from http://www0.health.nsw.gov.au/policies/gl/2009/pdf/GL2009_004.pdf

Currie, D. (2005). *Developing and Applying Study Skills: Writing Assignments, Dissertations and Management Reports.* CIPD Publishing.

Czerwinski, S. J. (2009). *Disaster Recovery: Past Experiences Offer Insights for Recovering from Hurricanes Ike and Gustav and Other Recent Natural Disasters.* DIANE Publishing.

Da Silva, J. (2010). *Lessons from Aceh: key considerations in post-disaster reconstruction.* ractical Action Publishing Limited.

Dangerfield, B., Brailsford, S., & Churilov, L. (2014). *Discrete-Event Simulation and System Dynamics for Management Decision Making* (1st ed.). Wiley.

Daniell, J. E., Wenzel, F., & Khazai, B. (2010). *The Cost of Historic Earthquakes Today – Economic Analysis since 1900 through the use of CATDAT.* Perth, Western Australia : Australian Earthquake Engineering Society .

De Vries, H., Nilakant, V., Walker, B., & Baird, R. (2015). Post-disaster recovery: A study of a special purpose business alliance structure. *ANZAM Conference.* Christchurch: University of Canterbury.

Dehmer, M., Emmert-Streib, F., & Shi, Y. (2017). Quantitative Graph Theory: A new branch of graph theory and network science, In Information Sciences. *Information Sciences, 418-419*, 575-580.

Denscombe, M. (2003). *The Good Research Guide for Small-scale Social Research Projects, 2nd ed.* Open University Press.
Dojutrek, M. S., Labi, S., & Dietz, J. E. (2016). A multi-criteria methodology for measuring the resilience of transportation assets. *International Journal of Disaster Resilience in the Built Environment, 7*(3), 290-301.
Dragulanescu, I. V., & Androniceanu, A. (2017). Risk Management in Global Sourcing. 695-702. Varazdin: Varazdin Development and Entrepreneurship Agency (VADEA).
Dulal, H., Shah, K., & Ahmad, N. (2009). Social equity considerations in the implementation of Caribbean climate change adaptation policies. *Sustainability, 1*, 363-383.
Dunnette, M. D., Campbell, J., & Jaastad, K. (1963). The effect of group participation on brainstorming effectiveness for 2 industrial samples. *Journal of Applied Psychology, 47*(1), 30-37.
Eker, S., & Zimmermann, N. (2016). Using Textual Data in System Dynamics Model Conceptualization. *Systems, 4*(28), 1-14.
EQC. (2012). *Canterbury Home Repair Programme*. Retrieved 8 8, 2018, from https://www.eqc.govt.nz/canterbury-earthquakes/home-repair-process/chrp
Erik, P., & Antvik, S. (2009). *Earned Value Management - an introduction.* Philipson Biz.
ERSA. (2014). *Disaster Risk Assessments for Local Governments: a Practitioner's Guide.* AU: Environmental Risk Science and Audit.
Esakcen, S. (1998). *A Review of Brainstorming Research: Six Critical Issues for Inquiry* (Volume 302 of Monograph series ed.). Creative Research Unit, Creative Problem Solving Group-Buffalo.
Escobar, M., Aguarón, J., & Moreno-Jiménez, J. (2004). A note on AHP group consistency for the row geometric mean prioritisation procedure. *European Journal of Operational Research, 153*, 318-322.
Fahimnia, B., Tang, C. S., Davarzani, H., & Sarkis, J. (2015). Quantitative models for managing supply chain risks: A review. *European Journal of Operational Research, 247*(1), 1-15.
Fiss, P. C. (2010). A Fuzzy Set Approach to Typologies in Organization Research. *Academy of Management Journal, in press*.
Fix, M., Papademetriou, D., Batalova, J., Terrazas, A., Yi-Ying Lin, S., & Mittelstadt, M. (2009). *Migration and the Global Recession.* Washington, DC: Migration Policy Institute.
Forrester, J. (1992). Policies, decisions and information sources for modelling. *Eur. J. Oper. Res., 59*, 42-63.
Frame, D. (2002). *The New Project Management: Tools for an Age of Rapid Change, Complexity, and Other Business Realities.* San Francisco: Wiley & Sons.
Frigo, M. L., & Anderson, R. J. (2011). What Is Strategic Risk? http://www.markfrigo.org/What_is_Strategic_Risk_Management_-_Strategic_Finance_-_April_2011.pdf.
Galorath, D. (2006). Risk Management Success Factors. *PM World Today, 8*(11).
Geonet. (2011, August 1). *Historical Earthquakes*. Retrieved from GeoNet: www.geonet.org.nz
Geraldi, J. (2008). The balance between order and chaos in multi-project firms: a conceptual model. *International Journal of Project Management, 26*(4), 348-356.
Giovinazzi, S., Wilson, T., Davis, C., Bristow, D., Gallagher, M., Schofield, A., & Tang, A. (2011). Lifelines Performance and Management Following the 22 February 2011 Christchurch Earthquake. *Highlights of Resilience. Bulletin of the New Zealand, 44*(4), 402-417.
Godfrey, P., & Sillitto, H. (2015). Architecting Complex Systems in new domains and problems. UK: Faculty of Engineering, University of Bristol.
Goepel, K. D. (2013). Implementing the Analytic Hierarchy Process as a Standard Method for Multi-Criteria Decision Making In Corporate Enterprises. Kuala Lumpur: https://bpmsg.com.
Goh, C. S., Abdul-Rahman, H., & Samad, Z. A. (2013). Applying Risk Management Workshop for a Public Construction Project: Case Study. *Journal of Construction Engineering and Management* , 573-580.

Grabowski, M., & Roberts, K. (1999). Risk mitigation in virtual organisations. *Organisational Science, 10*(6), 704-722 .
Hall, R., Aitchison, P., & Kocay, W. (1994). Causal policy maps of managers: Formal methods for elicitation and analysis. *Syst. Dyn. Rev. 1994, 10, 337–360., 10*, 337:360.
Hastak, M., & Shaked, A. (2000). Model for International Construction Risk Assessment. Journal of Management in Engineering. *Journal of Management in Engineering, 16*(1), 59-69.
Hillson, D. (2012). *Practical Project Risk Management: The ATOM Methodology.* Berrett-Koehler Publishers.
Hlaing, N., Singh, D., Tiong, R., & Ehrlich, M. (2008). Perceptions of Singapore construction contractors on construction risk identification. . *Journal of Financial Management of Property and Construction, 13*(2), 85-95.
Holt, G. (2014). Asking questions, analysing answers: relative importance revisited. . *Construction Innovation: Information, Process, Management, 14*(1), 2-16.
Hosseini, M. R., Chileshe, N., Jepson, J., & Arashpour, M. (2016). Critical success factors for implementing risk management systems in developing countries. *Construction Economics and Building, 16*(1), 18-32.
Howes, T., & Cheesebrough, T. (2013). Infrastructure impact and recovery following the 2010–2011 earthquakes in Christchurch, New Zealand. *Proceedings of the ICE - Civil Engineering, 166*(5), 57-64.
Huntjens, P., Claudia Pahl-Wostl, B. R., Schlüter, M., Flachner, Z., Neto, S., Koskova, R., . . . Kiti, I. N. (2011). Adaptive Water Management and Policy Learning in a Changing Climate: a Formal Comparative Analysis of Eight Water Management Regimes in Europe, Africa and Asia. *Environmental Policy and Governance , 21*(3), 145-163.
ICSU. (2015). *Disaster Risks Research and Assessment to Promote Risk Reduction and Management.* ICSU.
ISO 31000. (2009). *Risk management, Principles and guidelines.* Geneva, Switzerland: International Organization for Standardization.
ISO 31000. (2018). *Risk management, Principles and guidelines.* Geneva, Switzerland: International Organization for Standardization.
ISO official website. (2018). *ISO 31000 - Risk management*. Retrieved 12 12, 2018, from https://www.iso.org/iso-31000-risk-management.html
Iverson, D. (2013). *Strategic Risk Management: A Practical Guide to Portfolio Risk Management* (1 ed.). Singapore: John Wiley & Sons.
Jia, G., Ni, X., Chen, Z., Hong, B., Chen, Y., Yang, F., & Lin, C. (2013). Measuring the maturity of risk management in large-scale construction projects. *Automation in Construction, 34*, 56–66.
Johnson, B., & Christensen, L. (2008). *Educational research: Quantitative, qualitative, and mixed approaches .* Thousand Oaks, CA: Sage Publications.
Johnson, R. B., & Onwuegbuzie, A. J. (2004). Mixed methods research: A research paradigm whose time has come. *Educational Researcher, 33*(7), 14-26.
Kangari, R. (1995). Risk management perceptions and trends of US construction. *Journal of Construction Engineering and Management. , 121*(4), 422-429.
Kanshieva, A. (2012). *Sustainability-driven entrepreneurship as a tool to increase rural resilience in Russia: framework for transfer of the European experience* (PhD thesis ed.). Russia: University of Padova.
Karthikeyan, R., Venkatesan, K., & Chandrasekar, A. (2016). A Comparison of Strengths and Weaknesses for Analytical Hierarchy Process. *Journal of Chemical and Pharmaceutical Sciences*, 12:15.
Kim, H., & Andersen, D. (2012). Building confidence in causal maps generated from purposive text data: Mapping transcripts of the federal reserve. *Syst. Dyn. Rev., 28*, 311:328.
Kirkwood, C. W. (2013, Dec. 1). *System Dynamics Methods: A Quick Introduction.* Retrieved March 5, 2015, from http://www.public.asu.edu/~kirkwood/sysdyn/SDIntro/SDIntro.htm

Klir, G. J. (1991). *Facets of Systems Science (IFSR International Series in Systems Science and Systems Engineering)* . Springer.
König, D. (1935). *Theorie der endlichen und unendlichen Graphen.* Chelsea Publishing.
Krivokapić-Skoko, B. (2003). Boolean Algebra and the Comparative Method: Feature and Applications to Social Sciences". Paper presented at the second workshop on Research Methodology RM . Amsterdam: the Royal Netherlands Academy of Art.
Kwortnik, R. (2003). Clarifying fuzzy hospitality-management problems with depth interviews and qualitative analysis. *Cornell Hotel and Restaurant Administration Quarterly, 44*(2), 117-129.
Lam, J. (2003). *Enterprise Risk Management: From Incentives to Controls.* New Jersey: John Wiley & Sons.
Lancaster, G., Dodd, S., & Williamson, P. (2004). Design and analysis of pilot studies: recommendations for good practice. *Journal of Evaluation in Clinical Practice, 10*(2), 307-312.
Last, J. (2001). *International epidemiological association. A dictionary of epidemiology* (4th ed.). New York: Oxford University Press.
Lavell, A. (2003). Local Level Risk Management: Concept and Practices. Quito, Ecuador.: CEPRE-DENAC-UNDP.
Lavell, A. (2009). Unpacking Climate Change Adaptation and Disaster Management: Searching for the Links and Differences: A Conceptual and Epistemological Critique and Proposal. Bogota, Colombia.: FLACSO.
Lazarus, R. (2000). Toward better research in stress and coping. *American Psychologist, 55*(6), 665-673.
Li, F., Phoon, K. K., F.ASCE, Du, X., & Zhang, M. (2013). Improved AHP Method and Its Application in Risk Identification. *J. Constr. Eng. Manage., 139*, 312-320.
Lichtman, M. (2006). *Qualitative research in education: A user's guide* . Thousand Oaks, CA: Sage Publications.
Lichtman, M. (2012). *Qualitative Research in Education: A User's Guide: A User's Guide* (illustrated ed.). Washington, D.C.: SAGE.
Lindlof, T., & Taylor, B. (2002). *Qualitative Communication Research Methods* (2nd ed.). Thousand Oaks, CA: SAGE Publications.
Liu, J., Zou, P., & Gong, W. (2013). Managing project risk at enterprise level: Exploratory case studies in China. *J. Constr. Eng. Management, 10*(1061), 1268-1274.
Luna-Reyes, L., & Andersen, D. (2003). Collecting and analyzing qualitative data for system dynamics: Methods and models. *Syst. Dyn. Rev. , 19*, 271:296.
Lunsford, A. (2005). *The everyday writer* (3rd ed.). Boston: Bedford/St. Martin's.
Lyons, T., & Skitmore, M. (2004). Project risk management in the Queensland engineering construction industry: a survey. *International Journal of Project Management, 22*, 51-61.
Manaba, N. A., Othmanb, S. N., & Kassim, I. (2012). Enterprise-Wide Risk Management Best Practices: The Critical Success Factors. *International Journal of Sustainable Development, 04*(03), 87-96.
Mannakkara, S. (2014). *A Framework for building back better during post disaster reconstruction and recovery.* Auckland: The University of Auckland.
Marsh Risk Consulting. (2012). *ACRP: Application of Enterprise Risk Management at Airports.* NY: Transportation Research Board.
Mayer, J., & Fagundes, L. L. (2009). A model to assess the maturity level of the risk management process in information security, in: Proceedings of the International Symposium on Integrated Network Management. *IFIP/IEEE*, 61–70.
McIntosh, K., & McCable, B. (2003). Risk and Benefits Associated with International Construction-Consulting Joint Ventures in the English-Speaking Caribbean. *Canadian Journal of Civil Engineering, 30*, 1143-1152.

Molenaar, K. R., Anderson, S. D., & Schexnayder, C. J. (2010). *Guidebook on Risk Analysis Tools and Management Practices to Control Transportation Project Costs.* United States: Transportation Research Board.
Montz, B. E., Tobin, G. A., & Hagelman, R. R. (2017). *Natural hazards : explanation and integration.* New York: The Guilford Press.
Moritz, M., Giblin, J., Ciccone, M., Davis, A., Fuhrman, J., Kimiaie, M., . . . Senn, M. (2011). Social Risk-Management Strategies in Pastoral Systems: A Qualitative Comparative Analysis. *Cross-Cultural Research, 45*(3), 286-317.
Munich, R. (2014). *Topics Geo - Annual review of natural catastrophes 2013. Analyses, assessments, positions.* Retrieved 8 1, 2015, from http://www.munichre.com/site/corporate/get/documents_E1043212252/mr/assetpool.shared/Documents/5_Touch/_Publications/302-08121_en.p
Mustafa, M. A., & Al-Bahar, J. F. (1991). Project Risk Analytic Assessment Using the Hierarchy Process. *IEEE Transactions On Engineering Management, 38*(1), 46:55.
Naoi, M., Seko, M., & Ishino, T. (2012). Earthquake Risk in Japan: Consumers' Risk Mitigation Responses After the Great East Japan Earthquake. *Journal of Economic Issues, 46*(2).
Nasirzadeh, F., Afshar, A., Khanzadi, M., & Howick, S. (2008). Integrating system dynamics and fuzzy logic modelling for construction risk management. *Construction Management and Economics , 26*(11), 1197-1212.
Newell, W. H. (2001). A Theory of Interdisciplinary Studies. *School of Interdisciplinary Studies, 19*, 1-25.
Nguyen Phuong, N., & Yuansheng, L. (2012). *Critical Analysis of Risk Management and Significant Impacts of its Application on Sichuan Post-earthquake Reconstruction Project.* Umeå School of Business.
Nicolis, G., & Prigogine, I. (1989). *Exploring complexity: an introduction.* New York: W.H. Freeman.
Noktehdan, M. (2017). *Innovation in Construction: An innovation Framework for Infrastructure reconstruction Projects.* Auckland: The University of Auckland.
O'Donnell, E. (2005). Enterprise risk management: A systems-thinking framework for the event identification phase. *International Journal of Accounting Information Systems, 6*(3), 177-195.
OECD. (2006). *OECD Studies in Risk Management Japan earthquakes.* France: OECD Publications.
Office of the Auditor-General . (2013). *Effectiveness and efficiency of arrangements to repair pipes and roads in Christchurch*. Retrieved 6 5, 2018, from https://www.oag.govt.nz/2013/scirt/docs/oag-scirt.pdf
Official CERA website. (2012). *Recovery Strategy*. Retrieved 8 14, 2014, from http://cera.govt.nz/
OGC. (2007). *Management of Risk: Guidance for Practitioners.* UK: Office of Government Commerce.
Olson, D. L., & Wu, D. D. (2008). *Enterprise Risk Management.* WDC: World Scientific.
Ophiyandri, T., Amaratunga, D., & Pathirage, C. (2013). Risk Assessment on Community-Based Post-Disaster Housing Reconstruction Project. In: International Post Graduate Research Conference:. Salford, UK.: IPGRC.
Osborn, A. (1963). *Applied imagination: Principles and procedures of creative problem solving* (3rd ed.). New York: Charles Scribner's Sons.
Osipova, E., & Eriksson, P. E. (2013). Balancing control and flexibility in joint risk management: Lessons learned from two construction projects. *International Journal of Project Management, 31*, 391-399.
Page, L., Brin, S., Motwani, R., & Winograd, T. (1999). *The Pagerank citation ranking: Bringing order to the web.* Stanford InfoLab: Technical Report.
Palliyaguru, R., Amaratunga, D., & Baldry, D. (2014). *Constructing a holistic approach to disaster risk reduction: the significance of focusing on vulnerability reduction.* Oxford, UK: John Wiley and Sons.

Parker, M., & Steenkamp, D. (2012). *The economic impact of the Canterbury earthquakes.* Wellington: Reserve Bank of New Zealand:Bulletin.
Perera, B., Dhanasinghe, I., & Rameezdeen, R. (2009). Risk management in road construction: the case of Sri Lanka. *Int J St Prop Manage, 13*(2), 87–102.
Pezza, D., & Pinto, A. (2018). Applying Systems Thinking to Coastal Infrastructure Systems. *Public works management and policy, 24*(1), 71-87.
Phillips, M., & Lu, J. (2018). A quick look at NVivo. *Journal of Electronic Resources Librarianship , 30*(2), 104-106.
PMI. (2013). *Organizational Project Management Maturity Model (OPM3)* (5nd ed.). Newtown Square, Philadelphia, USA: Project Management Institute (PMI).
Prieto, B., & Whitaker, C. (2011). Post Disaster Engineering And Construction. *PM World Today, XIII*(IX), 1-18.
Project Management Institute (PMI). (2013). *Project management body of knowledge (PMBOK)* (5th ed.). Newtown Square: Project Management Institute.
Punyamurthula, S., & Badurdeen, F. (2018). Assessing Production Line Risk using Bayesian Belief Networks and System Dynamics. *Procedia Manufacturing, 26*, 76-86.
QLD. (2016). *Disaster Management Strategic Policy Framework.* Retrieved 6 2, 2018, from http://www.disaster.qld.gov.au/dmg/st/Documents/H1102-QFES-Risk-Assessment-Process-Handbook.pdf
QSR International. (2017). Nvivo 11. QSR International.
Rabinovich, M., & Kacen, L. (2010). Advanced relationships between categories analysis as a qualitative research tool. *J. Clin. Psychol, 66*, 698:708.
Radzicki, M. J., & Taylor, R. A. (2008). *Origin of System Dynamics: Jay W. Forrester and the History of System Dynamics.* U.S. : Department of Energy's.
Ragin, C. C. (2000). *Fuzzy-Set Social Science.* Chicago: University of Chicago Press.
Ragin, C. C. (2010). *User's Guide to Fuzzy-Set/Qualitative Comparative Analysis 2.0.* Irvine, California: Department of Sociology, University of California.
Ragin, C., & Davey, S. (2014). *fs/QCA [Computer Programme]* (2.5/3.0 ed.). Irvine, CA: University of California.
Ram, J., & Corkindale, D. (2014). How “critical” are the critical success factors (CSFs)? *Business Process Management, 20*(1), 151-174.
Ranong, P. N., & Phuennga, W. (2009). *Critical Success Factors for effective risk management procedures in financial industries.* Thailand: Umea University.
Rao, R., Zhang, X., Shi, Z., Luo, K., Tan, Z., & Feng, Y. (2014). A Systematical Framework of Schedule Risk Management for Power Grid Engineering Projects’ Sustainable Development. *Sustainability, 6*, 6872-6901.
Rihoux, B., & Ragin, C. C. (2008). *Configurational Comparative Methods: Qualitative Comparative Analysis (QCA) and Related Techniques* (eds ed.). London and Thousand Oaks: CA: Sage.
Rimbock, A., & Loipersberger, A. (2013). Integral risk management: steps on the way from theory to practice. *Nat Hazards, 67*, 1075-1082.
Rittenberg, L., & Martens, F. (2014). *Enterprise Risk Management: Understanding and Communicating Risk Appetite.* Retrieved 8 1, 2015, from www.coso.org
Rodrigues, A. (2001). Managing and modelling project risk dynamics: a system dynamics based framework. London: 4th European PMI conference.
Rueda-Benavides, J. A., & Gransberg, D. D. (2016). Effective risk management strategies in construction and maintenance indefinitely delivery/indefinitely quantity contracts. *Transportation Research Board Annual Meeting*, 16-62.
Saaty, T. (1980). *Multicriteria decision making: The analytic hierarchy process* (2nd ed.). New York, USA.: McGraw Hill.
Saaty, T. L., & Peniwati, K. (2008). *Group Decision Making: Drawing out and Reconciling Differences.* Pittsburgh, Pennsylvania: RWS Publications.

Sandberg, J. (2005). How do we justify knowledge produced within Interpretive approaches? *Organizational Research Methods, 8*(1), 41–68.
Schieg, M. (2006). Risk management in construction project management. *Journal of Business Economics and Management, 7*(2), 77-83.
Schnarwiller, R. (2011). *Closing the financial gap: Public-private innovations in disaster risk financing*. Retrieved 6 24, 2017, from www.swissre.com/rethinking/crm/Closing_the_financial_gap.html
SCIRT. (2016). *SCIRT Learning Legacy*. Retrieved 7 28, 2018, from https://scirtlearninglegacy.org.nz/
SCIRT. (2016). *Stronger Christchurch Infrastructure Rebuild Team website*. Retrieved 8 14, 2016, from http://strongerchristchurch.govt.nz/
Senge, P. (1990). *The Fifth Discipline – The art and practice of the learning organisation.* Century Business: ISBN 0-7126-56871.
Shafique, K. (2016). The success of Post-Natural Disaster Reconstruction Projects–Significance of Community Perspective. *International Journal of Business and Management, 11*(9).
Sharma, S., & Pratap, R. (2013). A Case Study of Risks Optimization Using AHP Method. *International Journal of Scientific and Research Publications, 3*(10), 1:6.
Shaw, K., & Theobald, K. (2011). Resilient local government and climate change interventions in the UK. *Local Environment, 16*(1), 1-15.
Skoko, H. (2013). Systems Theory Application to Risk Management in Environmental and Human Health Areas. *Journal of Applied Business and Economics, 14*(2), 95:111.
Smithson, M., & Verkuilen, J. (2006). *Fuzzy Set Theory. Applications in the Social Sciences.* London: Sage.
Sobremisana, V., & Pilar, N. (2014). Disaster Risk Reduction Management in the City of Mandaluyong: Focus on Earthquake Impact Reduction. *International Archive of Applied Sciences and Technology, 5*(1), 11-21.
Ssemaluulu, P., & Williams, D. (2006). *Complexity and Risk in IS Projects: A System Dynamics Approach.* (J. Kizza, J. Aisbett, A. Vince, & T. Wanyama, Eds.) Kampala: Fountain Publishers.
Statistics New Zealand. (2012). *Foreign Workers Flock to Christchurch Rebuild*. Retrieved 8 12, 2018, from https://www.critic.co.nz/news/article/3152/foreign-workers-flock-to-christchurch-rebuild
Sterman, J. D. (2000). *Business Dynamics Systems Thinking and Modelling for a Complex World.* Boston: Irwin McGrawHill.
Stevenson. (2013). Does Technology have an Impact on Learning? A Fuzzy Set Analysis of&xnbsp;Historical Data on the Role of Digital Repertoires in Shaping the Outcomes of Classroom Pedagogy. *Computers & Education, 69*(0), 148-158.
Stevenson, J. R. (2014). Organizational Resilience after the Canterbury Earthquakes: A Contextual Approach. PhD Thesis. Christchurch, NZ: University of Canterbury.
Strauss, A., & Corbin, J. (1998). *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory.* London, UK: Sage Publications Thousan Oaks.
Subramanyan, H., Sawant, P. H., & Bhatt, a. V. (2012). Construction Project Risk Assessment: Development of Model Based on Investigation of Opinion of Construction Project Experts from India. *Journal of Construction Engineering and Management* , 409-421.
Sum, R. (2015). Risk management decision-making: the analytic hierarchy process approach. *Journal for International Business and Entrepreneurship Development, 8*(2), 108-127.
Tam, C., Zeng, S., & Deng, Z. (2004). Identifying Elements of Poor Construction Safety Management in China. *Safety Science, 42*, 569-586.
Tamura, K. (2013). Development of a Practical Roal Disaster Management System Based on Risk Management Techniques. *Journal of JSCE, 1*, 569-582.
The Controller and Auditor General of New Zealand. (2017). *Part 3: An alliance procurement strategy*. Retrieved 5 30, 2018, from https://www.oag.govt.nz/2013/scirt/part3.htm

Toledo, R., Engler, A., & Ahumada, V. (2011). Evaluation of Risk Factors in Agriculture: An Application of AHP Methodology. *Chilean Journal of Agricultural Research, 1*(71), 114-121.
Toole, T. M. (2005). A Project Management Causal Loop Diagram. London, UK: ARCOM Conference.
Touchette, P. E., MacDonald, R. F., & Langer, S. N. (1985). A Scatter Plot For identifying Stimulus of Problem Behavior. *Journal of Applied Behavior Analysis, 18*, 343-351.
UN. (2015). *Sendai Framework for Disaster Risk Reduction 2015 – 2030*. Retrieved 8 20, 2016, from http://www.preventionweb.net/files/43291_sendaiframeworkfordrren.pdf, Accessed on August 20, 2016.
UNISDR. (2004). *Living with risk: a global review of disaster reduction initiatives*. Retrieved 8 7, 2016, from http://www.unisdr.org/we/inform/publications/657
UNISDR. (2009). *Global Assessment Report on Disaster Risk Reduction: Risk and Poverty in a Changing Climate – Invest Today for a Safer Tomorrow.* Geneva, Switzerland: United Nations International Strategy for Disaster Reduction.
UNISDR. (2011). *Global Assessment Report on Disaster Risk Reduction. Revealing Risk, Redefining Development.* Geneva, Switzerland: United Nations International Strategy for Disaster Reduction.
UNISDR. (2013). *Global assessment report on disaster risk reduction*. Retrieved 4 20, 2016, from https://www.unisdr.org/we/inform/publications/33013
UNISDR. (2013). *UN Secretary-General warns: "Economic losses from disasters are out of control"*. Retrieved 6 8, 2018, from https://www.unisdr.org/archive/33003
UNISDR. (2015). *Disaster Risk Reduction*. Retrieved 12 4, 2015, from http://www.unisdr.org/who-we-are/what-is-drr
United Nations Development Programme (UNDP). (2010). *Bureau for Crisis Prevention and Recovery: Disaster Risk Assessment.* NY: United Nations.
University of South Australia. (2004). *Risk Management: Its Importance During the Conceptual Stage of Construction Projects in Australia.* Australia: University of South Australia.
Van Niekerk, D. (2007). Disaster risk reduction, disaster risk management and disaster management: Academic rhetoric or practical reality. *Disaster Management South Africa, 4*(1).
Van, C., & Kingma, N. (2009). Disaster Risk Management. In C. van Westen (Ed.). In *Multihazard risk assessment: Distance education course/Guide book.* United Nations University.
Vlachos, I. K., & Sergiadis, G. D. (2009). *Intuitionistic Fuzzy Image Processing.* Greece: Aristotle University of Thessaloniki.
Wang, Q.-F., Ning, X.-Q., & You, J. (2005). Advantages of System Dynamics Approach in Managing Project Risk Dynamics. *Journal of Fudan University, 44*(2), 201-206.
Wang, W. (2010). *The Risk Management of Safety and Dependability: A Guide for Directors, Managers and Engineers* (ISBN 9781845699383. p 312. ed.). Elsevier.
Wasserman, S., & Faust, K. (1994). *Social Network Analysis: Methods and Applications.* Cambridge University Press.
Wisner, B. (2011). Are we there yet? Reflections on integrated disaster risk manage-ment after ten years. *Journal of Integrated Disaster Risk Management, 1*, 1:14.
Wood, H. L., & Ashton, P. (2017). *The Factors of Project Complexity*. Retrieved 8 20, 2017, from https://www.irbnet.de/daten/iconda/CIB_DC24048.pdf
Woolf, N. H., & Silver, C. (2017). *Qualitative Analysis Using NVivo.* New York: Taylor and Francis.
Wu, D. D., Kefan, X., Hua, L., Shi, Z., & L.Olsond, D. (2010). Modelling technological innovation risks of an entrepreneurial team using system dynamics: An agent-based perspective. *Technological Forecasting and Social Change, 77*(6), 857-869.
Xiang, P., Zhou, J., Zhou, X., & Ye, K. (2012). Construction Project Risk Management Based on the View of Asymmetric Information. *Journal of Construction Engineering and Management* , 1303-1311.

Yearworth, M., & White, L. (2013). The uses of qualitative data in multimethodology: Developingcausalloopdiagrams during the coding process. *Eur. J. Oper. Res, 231*, 151:161.
Yin, R. (2003). *Case Study Research: Design and Methods.* CA: Sage, Newbury Park.
Yin, R. (2009). *Case Study Research, 4th ed, SAGE Publications, California.* California: 4th ed, SAGE Publications.
Yu, T., Shen, G. Q., Shi, Q., Lai, X., Li, C. Z., & Xu, K. (2017). Managing social risks at the housing demolition stage of urban redevelopment projects: A stakeholder-oriented study using social network analysis. *International Journal of Project Management, 35*(6), 925-941.
Zhao, X., Hwang, B., & Low, S. (2014). Investigating Enterprise Risk Management Maturity in Construction Firms. *Journal of Construction Engineering Management, 140*(8).
Zhao, X., Hwang, B.-G., & Low, S. P. (2013). Critical success factors for enterprise risk management in Chinese construction companies. *Construction Management and Economics, 31*(12), 1199-1214.
Zhao, X., Hwang, B.-G., & Low, S. P. (2013). Developing fuzzy enterprise risk management maturity model for construction firms. *J. Constr. Eng. Manage., 139*(9), 1179–1189.
Zou, P., Chen, Y., & Chan, T.-Y. (2010). Understanding and improving your risk management capability: assessment model for construction organizations. *Journal of Construction Engineering and Management, 136*(8), 854–863.
Zou, P., Zhang, G., & Wang, J. (2006). Identifying key risks in construction projects: life cycle and stakeholder perspectives. *International Journal of Construction Management*, 1-14.

Appendix A: Human Ethics approval

UC
UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

HUMAN ETHICS COMMITTEE

Secretary, Rebecca Robinson
Telephone: +64 03 369 4588, Extn 94588
Email: human-ethics@canterbury.ac.nz

Ref: HEC 2016/59

8 June 2018

Ashraf El Said Abouelezz
CNRE
UNIVERSITY OF CANTERBURY

Dear Ashraf

The Human Ethics Committee advises that your research proposal "An Integrated Risk Management Model for Post-disaster Projects in the Construction Sector: a Proposal after the Canterbury Earthquakes, New Zealand" has been considered and approved.

Please note that this approval is subject to the incorporation of the amendments you have provided in your email of 10th May 2018.

Best wishes for your project.

Yours sincerely

pp. R. Robinson

Professor Jane Maidment
Chair
University of Canterbury Human Ethics Committee

University of Canterbury Private Bag 4800, Christchurch 8140, New Zealand. www.canterbury.ac.nz

F E S

Appendix B: Survey questions

Introduction

.
This survey is a part of PhD research to identify the major differences between risk management procedure in business as usual projects namely as Traditional Risk Management (TRM) and risk management procedure for recovery project after a disaster namely as Post Disaster Risk Management (PDRM).

Survey contains 39 multiple choice questions and 1 text question and should take about 20-30 minutes.

Consent:
By continuing this survey, you giving the permission to use this information for research purposes and results may be published in academic journals after the review and approval of SCIRT alliance.

Confidentiality:
In all cases, company information will be confidential, no proprietary information will be shared and the privacy of the participants will be safeguarded. Data will be stored for up to 10 years with adequate provisions to maintain confidentiality.

For any additional information or inquiries, please feel free to contact me.

Researcher

Ashi Ezz | PhD Student, Civil Engineering Department, Canterbury Uni. | Email: ashi.ezz@pg.canterbury.ac.nz

- I agree to take part in this study

Demographic questions

.
The following set of questions are demographic questions to identify the characteristics of the participants.

8 questions

Q1. Name

Q2. What best describes your organization?

- Client
- Designer
- Main contractor (delivery team)
- Subcontractor / Supplier
- Government
- SCIRT (IST)
- External

Q3. Email

Q4. Current Position

- Top management
- Senior management
- Project manager
- Estimator
- Designer
- Administration and project controls
- Project team
- Others

Q5. How old are you?

- 18-25
- 55-64

- 26-34
- 35-54
- 65 or over

Q6. How many employees work in your organization?

- less 100
- 100 to 500
- 500 to 1000
- over 1000

Q7. How long have you been working in your organization?

- less than 2 years
- 2 to 5
- 5 to 10
- over 10 years

Q8. Could you please choose the level of your involvement in SCIRT program?

- Heavily involved (equal or more than 40 hours a week)
- Medium involvement (16 : 39 hours a week)
- Low involvement (16 : 8 hours a week)
- Barley involvement (less than 8 hours a week)
- No involvement
- Others

Q8A.
Please choose the type of your organization culture from the following types

- Clan: an organization that concentrates on internal maintenance with flexibility, concern for people, and sensitivity for customers.
- Hierarchy: an organization that focuses on internal maintenance with a need for stability and control.
- Adhocracy: an organization that concentrates on external positioning with a high degree of flexibility and individuality.
- Market: an organization that focuses on external maintenance with a need for stability and control.

Identify critical risks in post disaster projects

.
The following set of questions will be used to investigate the type of risks inside the three management level in SCIRT programme (client level, IST level, and delivery team level).

6 questions

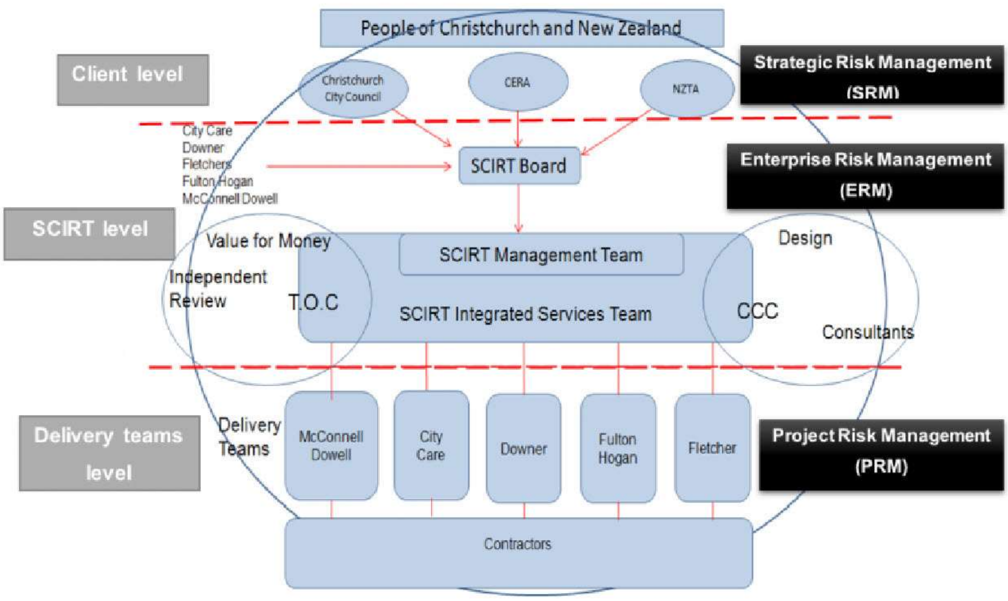


Figure 1: SCIRT workflow chart (SCIRT website, 2012)

Q9.
Please rate the following risks according to its impact on **project budget** where (10) is the highest and (0) is the lowest

	0	1	2	3	4	5	6	7	8	9	10
Lack of unity between stakeholders											
Lack of funding effects priorities / strategy											
Variations to the scope											
Continuity of natural hazard after construction start (Seismic activity, land settlement, floods, etc.)											
Tight project schedule											
Price inflation of construction materials											
Scope uncertainty											
Incomplete approval and other documents											
Others											

Q10. Please rate the following risks according to its impact on **project schedule** where (10) is the highest and (0) is the lowest

	0	1	2	3	4	5	6	7	8	9	10
Timing of strategic decisions not aligning with schedule demands											
Lack of unity between stakeholders											
Excessive approval procedures in administrative government departments											
Variations to the scope											
Scope uncertainty											
Insurance cover difficulties											
Change of Government											
Competitive Tension between Delivery Teams - Adverse effects											
Poor communication											
Continuity of natural hazard (Seismic activity, land settlement, floods, etc.)											
Others											

Q11. Please rate the following risks according to its impact on **project scope** where (10) is the highest and (0) is the lowest

	0	1	2	3	4	5	6	7	8	9	10
Timing of strategic decisions not aligning with schedule demands											
Lack of unity between stakeholders											

	0	1	2	3	4	5	6	7	8	9	10
Excessive approval procedures in administrative government departments											
Variations to the scope											
Scope uncertainty											
Insurance cover difficulties											
Change of Government											
Poor communication											
Continuity of natural hazard (Seismic activity, land settlement, floods, etc.)											
Others											

Q12. Please rate the following risks according to its impact on **project quality** where (10) is the highest and (0) is the lowest

	0	1	2	3	4	5	6	7	8	9	10
Tight project schedule											
Inexperienced staff											
Low management competency											
High performance or quality expectations											
Poor communication											
Continuity of natural hazard (Seismic activity, land settlement, floods, etc.)											
Variations to the scope											
Lack of coordination between project participants											
Lack of resources											
Others											

Q13. Please rate the following risks according to its impact on **project safety and environment** where (10) is the highest and (0) is the lowest

	0	1	2	3	4	5	6	7	8	9	10
Tight project schedule											
Poor communication											
Inexperienced staff											
Lack of resources											
Variations to the scope											
Inadequate or insufficient site information (soil test and survey report)											
Low management competency											
High performance or quality expectations											
Serious noise pollution caused by construction											
Continuity of natural hazard (Seismic activity, land settlement, floods, etc.)											

	0	1	2	3	4	5	6	7	8	9	10
Others											

Q14.
Please rate the following **Macro risks including legal, political and social risks** according to its impact on **project success** where (10) is the highest impact and (0) is the lowest

	0	1	2	3	4	5	6	7	8	9	10
Political intervention into Program											
Uncertain scope											
Overlapping or conflict of Authorities relating to SCIRT activities											
Disruption in the community											
Continuity of natural hazard (Seismic activity, land settlement, floods, etc.)											
Community demand for information											
Change in government											
Lack of unity between stakeholders											
Changes to legislation											
Lack of clarity of standards arising from laws											
Others											

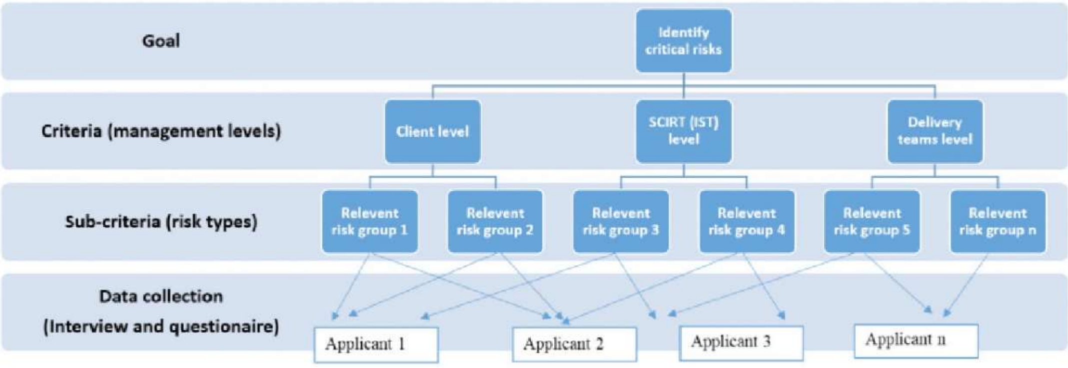
Analytic Hierarchy Process (AHP) anaylsis

.
The following set of questions will be used to identify the critical risks inside each management level using Analytic Hierarchy Process (AHP) Methodology.

The analytic hierarchy process (AHP) is a structured technique for organizing and analyzing complex decisions, based on mathematics and psychology.

4 questions

Analytical Hierarchical Process Methodology (AHP) process in this research



Q15.
Please mark the place along the segment to represent the most important risk group from your perspective between the pairs impacting the project?
For example (comparing the funding risks in client level against safety risks in delivery team)
Integrated Services Team (IST) *is a team of professional services consultants provide the design services for the SCIRT programme of work and provide the overarching tactical co-ordination for the infrastructure rebuild.*

	Absolute <<	equivalent	>> Absolute	
Overall risks in Client level	○	○	○	Overall risks in SCIRT (IST) level
Overall risks in SCIRT (IST) level	○	○	○	Overall risks in delivery team level
Overall risks in delivery team level	○	○	○	Overall risks in Client level

Q16.
Assume you are in **client side (owner side);** please mark the place along the segment to represent the most important risk from the client perspective between the pairs?

Macro risks refers to legal, political and social risks.

	absolute	<<	equivalent	>>	absolute	
Budget related risks	○	○	○	○	○	Schedule risks
Budget related risks	○	○	○	○	○	Safety and Enviro risks
Budget related risks	○	○	○	○	○	Quality risks
Budget related risks	○	○	○	○	○	Macro risks
Budget related risks	○	○	○	○	○	Scope risks
Schedule risks	○	○	○	○	○	Safety and Enviro risks
Schedule risks	○	○	○	○	○	Quality risks
Schedule risks	○	○	○	○	○	Macro risks
Schedule risks	○	○	○	○	○	Scope risks
Safety and Enviro risks	○	○	○	○	○	Quality risks
Safety and Enviro risks	○	○	○	○	○	Macro risks
Safety and Enviro risks	○	○	○	○	○	Scope risks
Quality risks	○	○	○	○	○	Macro risks
Quality risks	○	○	○	○	○	Scope risks
Macro risks	○	○	○	○	○	Scope risks

Q17. Assume you are in **SCIRT side (IST side);** please mark the place along the segment to represent the most important risk from IST perspective between the pairs?

Macro risks refers to legal, political and social risks.

	absolute	<<	equivalent	>>	absolute	
Budget related risks						Schedule risks
Budget related risks						Safety and Enviro risks
Budget related risks						Quality risks
Budget related risks						Macro risks
Budget related risks						Scope risks
Schedule risks						Safety and Enviro risks
Schedule risks						Quality risks
Schedule risks						Macro risks
Schedule risks						Scope risks
Safety and Enviro risks						Quality risks
Safety and Enviro risks						Macro risks
Safety and Enviro risks						Scope risks
Quality risks						Macro risks
Quality risks						Scope risks
Macro risks						Scope risks

Q18.
Assume you are in **Delivery Teams (DTs) side (main contractor side);** please mark the place along the segment to represent the most important risk from DTs perspective between the pairs?

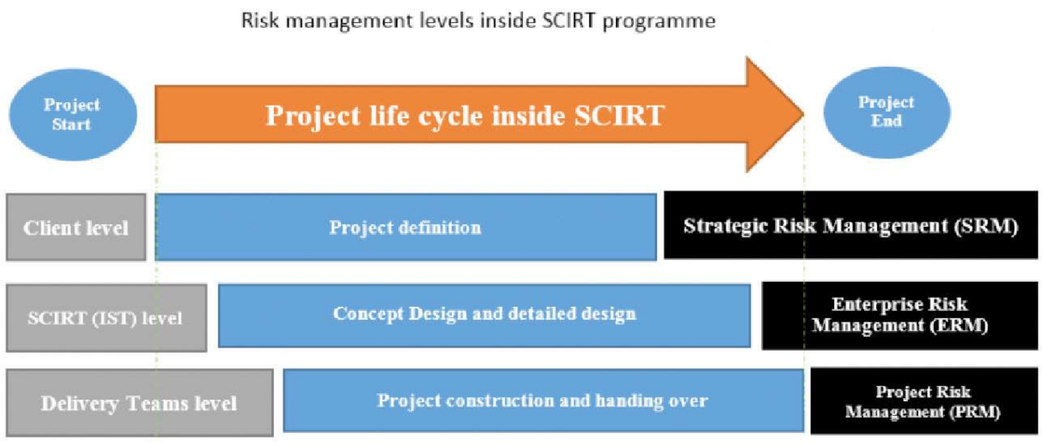
Macro risks refers to legal, political and social risks.

	Absolute	<<	equivalent	>>	Absolute	
Budget related risks						Schedule risks
Budget related risks						Safety and Enviro risks
Budget related risks						Quality risks
Budget related risks						Macro risks
Budget related risks						Scope risks
Schedule risks						Safety and Enviro risks
Schedule risks						Quality risks
Schedule risks						Macro risks
Schedule risks						Scope risks
Safety and Enviro risks						Quality risks
Safety and Enviro risks						Macro risks
Safety and Enviro risks						Scope risks
Quality risks						Macro risks
Quality risks						Scope risks
Macro risks						Scope risks

System Theory Method (STM)

.
The following set of questions will be used to investigate the interaction of risks between the three management levels in SCIRT programme (client level, IST level, and delivery team level) using System Theory Method (STM).

4 questions



Q19. Assume you are in ***client side***, please arrange the following risks from most critical number 1 to less critical number 6. (Drag and Drop)

- Financial risks
- Schedule risks
- Quality risks
- Scope risks
- Safety and environment risks
- Macro risks including Legal, Political and Social risks

Q20. Assume you are in ***SCIRT (IST) side***, please arrange the following risks from most critical number 1 to less critical number 6. (Drag and Drop)

- Financial risks
- Schedule risks
- Quality risks
- Scope risks
- Safety and environment risks
- Macro risks including Legal, Political and Social risks

Q21. Assume you are in ***Delivery Team side***, please arrange the following risks from most critical number 1 to less critical number 6. (Drag and Drop)

- Financial risks
- Schedule risks
- Quality risks
- Scope risks
- Safety and environment risks
- Macro risks including Legal, Political and Social risks

Q22.

Please rate the following risks for its influence ***ON*** each others from strong (4) to no influence (0).

(Risks are referred to your answer in questions no 19, 20, and 21).
(Please write the chosen risk from questions 19, 20 & 21 in the text box for your easy response)

	Client critical Risk 1 (the first risk you chose previously in question 19)	Client critical risk 2 (the second risk you chose previously in question 19)	SCIRT critical risk 1 (the first risk you chose previously in question 20)	SCIRT critical risk 2 (the second risk you chose previously in question 20)	Delivery team critical risk 1 (the first risk you chose previously in question 21)	Delivery team critical risk 2 (the second risk you chose previously in question 21)
Client critical Risk 1 (the first risk you chose previously in question 19)	4					
Client critical risk 2 (the second risk you chose previously in question 19)		4				
SCIRT critical risk 1 (the first risk you chose previously in question 20)			4			
SCIRT critical risk 2 (the second risk you chose previously in question 20)				4		
Delivery team critical risk 1 (the first risk you chose previously in question 21)					4	
Delivery team critical risk 2 (the second risk you chose previously in question 21)						4

Success Factors of risk management after disaster

.
The following set of questions will be used to identify the success factors of effective risk management in recovery projects after disaster.

17 questions

Q23. Are you familiar with ISO 31000 Risk Management Principles and Guidelines ?

- Yes
- No
- Not sure

Q24. In recovery projects after disaster, is the risk management guideline or policy of your company useful and regularly updated to maintain the new standards ?

- Yes
- No
- Not sure

Q25.
In recovery projects after disaster, how often does your organization change its guidelines or policies to manage risks?

- Rarely
- Sometimes
- Often
- All of the Time

Q26.
In recovery projects after disaster, how often does your organization provide risk management training courses?

- Never
- Once every six month
- Once or less a Month
- Once a year
- More than one a Month
- Others

Q27.
In recovery projects after disaster, what is your expectation from effective risk management in your organization?

	Very unlikely	Unlikely	Undecided	Likely	Very Likely
Reduce financial losses	○	○	○	○	○
Improve decision making	○	○	○	○	○
Improve communication with the stakeholders	○	○	○	○	○
Improve resource allocation	○	○	○	○	○
improve reputation and market position	○	○	○	○	○

Q28.
In recovery projects after disaster, who has the authority to establish risk management in your organization?

- ○ Executive Management Team
- ○ Chief Executive Officer (CEO)
- ○ Chief Financial Officer (CFO)
- ○ Internal auditor
- ○ Project manager
- ○ Others ______

Q29.
In recovery projects after disaster, how does your organization support its risk management policy?

	Very unlikely	Unlikely	Undecided	Likely	Very Likely
Setting up risk management teams	○	○	○	○	○
Clearly allocating risk management responsibilities	○	○	○	○	○
Allocating resources	○	○	○	○	○
Listening to problems from employees	○	○	○	○	○
Strictly obeying risk management policy	○	○	○	○	○
Regularly revising risk management plans	○	○	○	○	○

Q30. In recovery projects after disaster, how does your organization effectively communicate to reduce risk?

	Very unlikely	Unlikely	undecided	Likely	Very Likely
Developing understanding between management team and employee	○	○	○	○	○
Creating clear and trustworthy information	○	○	○	○	○
Regularly communicating among management and staff	○	○	○	○	○
Creating and maintaining a clear communication	○	○	○	○	○
Fast and sharp communication between management team and stakeholder	○	○	○	○	○

Q31. In recovery projects after disaster, how important do you think trust between all risk management levels including Client, IST and Project delivery teams?

Low	Medium	Strong	Don't know
○	○	○	○

Q32.

In recovery projects after disaster, in which areas do you see the need for changes to improve risk management in your organization?

- ☐ Improve methods of risk assessment
- ☐ Development of a corporate risk profile
- ☐ Implementation of early warning systems
- ☐ Integration of risk management into the corporate planning and controlling
- ☐ Improving the risk sensitivity of employees
- ☐ Creating and Testing Crisis Management Plans
- ☐ Others ______

Q33.

In recovery projects after disaster, how often you predict changes in your to happen in your organization (such as **Employee turnover)**?

	Very Unlikely	Unlikely	Undecided	Likely	Very Likely
Changes in your organization	○	○	○	○	○

Q34.
On a scale of 1 (less important) to 5 (very important), In your opinion, after disaster, what are the reasons of implementing a risk management process in your organization?

	1	2	3	4	5
Law	○	○	○	○	○
The potential for reduced insurance and liability costs	○	○	○	○	○
Requirements of Supervisor Committee	○	○	○	○	○
Reduced administrative costs	○	○	○	○	○
the potential improvement in employee and equipment performance	○	○	○	○	○
Reputation and enhanced image within your company for employees, the communist, clients and customers, and stakeholders	○	○	○	○	○
Reduced costs from injuries and illnesses	○	○	○	○	○

Q35.
In recovery projects after disaster, which of the following risk management activities does your company's top management perform?

- ☐ Review regular risk management reports
- ☐ Review and approve overall risk management policy and/or Enterprise Risk Management framework
- ☐ Review individual risk management policies for projects
- ☐ Review corporate strategy for alignment with the risk profile of the organization
- ☐ Review management's steps avoid any noncompliance with risk management policy
- ☐ Help establish and embed the risk culture of the enterprise; promote open discussions regarding risk
- ☐ Review incentive compensation plans to consider alignment of risks with rewards
- ☐ Establish the context
- ☐ Identify risks
- ☐ Analyze risks
- ☐ Evaluate risks
- ☐ Treat risks

Q36.
In recovery projects after disaster, how well developed are each of the following operational risk management stages at your organization?

	0	1	2	3	4	5	6	7	8	9	10
Establish the context											
Identify risks											
Analyze risks											
Evaluate risks											
Treat risks											

Q37.
In recovery projects after disaster, how effective do you think your organization is in managing each of the following types of risks?

	0	1	2	3	4	5	6	7	8	9	10
Financial risks											
Schedule risks											
Quality risks											
Scope risks											
Safety and environment risks											
Macro risks including Legal, Political and Social risks											

Q38.
In recovery projects after disaster, which of the following types of risk information does your organization currently report to the board of directors?

- ☐ Financial risks
- ☐ Schedule risks
- ☐ Quality risks
- ☐ Scope risks
- ☐ Safety and environment risks
- ☐ Macro risks including Legal, Political and Social risks

Q39.
In recovery projects after disaster, how challenging are each of the following for the risk management function in your organization (less challenging (0) high challenging (10)?

	0	1	2	3	4	5	6	7	8	9	10
Data management and availability											
Resourcing											
Analytics and reporting											
Risk governance											
Regulatory compliance											
Company culture											

Q40. What are your thoughts about risk management in recovery projects after disaster?

Appendix C: Interview questions

Q.01: What fundamental understanding do private and public organisations need to know when dealing with risks in recovery projects after a disaster?
Q.02: What are the issues that represent the greatest challenge to risk management for recovery project after disaster?
Q.03: What type of risks we expect to face in recovery projects after disaster not there in traditional risk management?
Q.04: What levels of oversight would prevent such risks of occurring and how can these risks be managed?
Q.05: Please choose the type of your organisation culture

- Clan: an organisation that concentrates on internal maintenance with flexibility, concern for people, and sensitivity for customers.
- Hierarchy: an organisation that focuses on internal maintenance with a need for stability and control.
- Adhocracy: an organisation that concentrates on external positioning with a high degree of flexibility and individuality.
- Market: an organisation that focuses on external maintenance with a need for stability and control.

Q.06: How is the organisation culture affecting the overall risk performance in recovery projects?
Q.07: What is required to overcome barriers in communication that prevent risks in recovery projects after disaster?
Q.08: How does the complexity of modern society and economy influence the way that risk is understood and managed.
Q.09: How do you think the best way to measure the performance of project risk management?
Q.10: How do you think about the formal risk management structures, and do you think the risk management functions are centralised or decentralised in your organisation and what is the best for recovery projects?
Q.11: How do you think about conducting independent review of risk management activities?
Q.12: What do you think about setting aside specific budgets for the risk management functions?
Q.13: In your opinion, what is the most important reason of implementing risk management process in your organisation?
Q.14: How are the following affecting the risk management performance in recovery projects?

- Quality assurance
- Costumer Demand
- Availability of resources
- Technological changes
- Competition on market
- Legally changes
- WSCs
- No of RFIs
- Productivity
- Project type
- Do you have factors in your mind?

Q.15. Which areas we did well and which areas do you see the need for changes?

- Improve methods of risk assessment
- Development of a corporate risk profile
- Implementation of early warning systems
- Integration of risk management into the corporate planning and controlling
- Improving the risk sensitivity of employees
- Creating and Testing Crisis Management Plans
- Other Actions, which

Appendix D: AHP calculation

Attached in a separate PDF file

Appendix E: Transcripts and Coding of Causal Loops Diagrams (CLD)

➢ *Introduction*

This appendix represents the transcripts from the participants' interviews. In addition, how it has been used in the coding procedure by NVivo 11 and Vensim software. The results have been organised in a way to be aligned with ISO31000 process, starting with the common areas of risk management, which includes establish context, risk assessment, risk treatment, monitoring and controlling, and then communications; then followed by other concepts mentioned in Table 8.1.

➢ *1 Establish context*

- **Event focus**

Participant P6 stated that in projects before disaster, we are normally dealing with single large project, then the risk management around that is aligned to the achieve this project, project team is working in the same direction, to achieve the same aspects to deliver the project successfully. In post-disaster situation, the atmosphere has been ***created already by some other event***. People aligned to fix and recover from that event. ***The attitude of people changes***, we will still need the ***culture of the organisation*** to align with the values of the business however, everybody focused in that event, so, after disaster ***people are aligned with the event***.

Participant P12 mentioned that in recovery projects, we have ***aftershocks***. The earthquake in most of people's eyes is ***one thing event***, however it is far out of that, people around Canterbury realised 20000 earthquakes later after the main shake, and it is ***ongoing risks,*** which is a big challenge. That defined the reason of implementing risk management in recovery projects is to identify the risks, the ongoing risks.

Participant P14 explained how risk is estimated in recovery projects. While estimating, we faced risk register after a disaster that have never seen in risk register in BAU. It is ***more event related, more related to earthquakes***, such as liquefactions, underground water, and reworks, which not have been in BAU. Moreover, the scope would increase dramatically, the volume of work would increase to avoid or minimise risk. Therefore, we looked to the likelihood and assessed all the risks and trying to quantify risks and mitigate these risks even it is a big challenge to quantify risks such as safety risks,

we don't want people to get injured. If something happens and we did not allow for it, that means the project budget could blow that is why it is important to have risk management in projects.

- **Understanding the situation for better-integrated risk management approach.**

Participant P24 explained one of the challenges that facing risk management professionals in recovery projects are to ***understand the situation and the type of risks***. For example, if we looked at Christchurch earthquakes as ***a disaster situation*** compare to a traditional contract, we understand risk better in traditional contact, ***we have time to assist and quantify the risks in traditional projects and much easier to manage***, where after a disaster situation, we have lot of stuff going on and it is just happening very quickly. In addition, almost hard to understand the risks around any construction activity, which are typically ***risks that associated with unknown or incomplete scope or things you cannot quantify***. Hence, in the recovery process, the work need to be done quickly even it is hard to fully quantify the risks. ***So obviously, the delivery teams are not keen to carry 100% of the risk in a disaster situation where it is not clearly identified and unknown, so we end up with a sharing risk alliance that the client carries most of the risk.*** Based on a contract and commercial agreement delivery teams are being paid of the work they are doing. It does not matter what risks you will face, like unforeseen ground conditions, delivery teams are going to get paid of the work they have done. It may affect the pain and gain situation, which they can get if they deliver on time and on budget, 12.5% on TOC, but if they come over TOC, then no profit. The chance of not being paid of the work done does not exist. ***It is the pain and gain model that SCIRT adopted to create some competition and to build some trust to construction companies to deliver the programme without high risk.***

- **Pre-disaster planning**

Participant P10 has mentioned that there was not ***enough understanding*** from most of the organisations that this crisis was going to happen in Christchurch in such scale. Some of the plans and the measure up haven't consider this expansion of work, the staff numbers jump from 300 persons in the beginning of the programme to 1500 persons and over 3000 persons from subcontractors. The recovery companies did not ***understand the risk of work scaling,*** so it was not plan for. Therefore, there was no ***proper pre-disaster planning*** of the risk of Christchurch having earthquake. The bigger picture of the risk was missing in the strategic risks.

Participant P19 illustrated that front planning enables early management action to mitigate risks in recovery projects. With no ***proper front risk management planning***, you will keep firefighting the whole time to reduce of minimise risks.

- **Clearer objectives in recovery projects (Zero harms, cost control, meet public expectations & reputation)**

Participant P11 explained the importance of having ***clear objectives*** in establishing the context in recovery projects including ***zero harm*** as safety of people is the first after disaster.

Participant P13 said that the reason of implementing risk management in recovery projects is ***profit*** because without it, construction companies do not exist which should be clear as objective besides ***reputation***.

Participant P15 also believed that risk management in recovery projects is money driven as if the risk happened, ***the cost*** will be on the organisation.

Participant P17 mentioned main goal of applying risk management in recovery projects is to ***finish the project in budget, meet the public expectations***. As a project manager, it is known that the risks are the first enemy of a project. It is to mitigate the risk before it eventuated and avoid any harm to ***company reputation.***

- **Organisation culture vs alliance culture**

Participant P18 thought that in project level; the ***varieties in cultures*** are clear and it is affecting the risk management and the way they are managing risks inside the projects. However, in the overhead structure, that ***organisation structure*** merged to be one, which called ***alliance culture*** and it is optimise to most effectively manage the risk. His is the value of the alliance to put the different culture aside and effectively manage the risks. ***Commercial gains*** also could be described as a risk management driver, which could influence all levels of project management in recovery projects.

- **Risk management leadership, governances and decision making**

Good risk management leadership and decision making has been an effective driver in the recovery projects. Participant P20 explained that using professional institutions to support the leaders with knowledge is the right way to add to the ***risk management leadership*** in recovery projects. For example, New Zealand institute of directors has good courses and publications about risk management. In any situation, we can structure risk management to dictate all your business management. If we start new enterprise especially after disaster, one of the first things we do is ***set the objectives*** of the enterprise. From a governor perspective; SCIRT best example of that, the objectives have been set in the alliance agreement. These objectives used to create ***the risk management framework,*** which fed also to the ***business management plans*** and how you will do with the work. The best benefit of early creating these objectives is ***to tie up the objectives with the risk management and the business plan***. It is the first step of establishing the context; which is in the ***government level***, not by delivery team. Moreover, Participant P20 illustrated that it is important to create separate risk management plans to critical areas and critical levels, such as risk management plans for central city, programme levels and projects levels.

Practically, participant P20 explained how that has been done inside SCIRT; every project has its risk register in project centre. The risk register for each project is a part of the design plan, which then becomes part of the TOC; the initial risk register is created by the designers, not by the delivery team. The designer creates risk register for the whole project, and then in the ECI, it been modified and reviewed. In the TOC, some of risks estimated and valued then also added percentage to cover small risks or risks with small probability. In BAU, the business is already well established, so everybody attitude around the business is established. Immediately after a disaster, it is very distracted, even after a while; it is not the same state of mind as before the disaster, it is ***fundamentally different***. ***In SCIRT, what has been faced is very different from BAU, which required different approach.***

- **Intentionality**

Nevertheless, participant highlighted the importance of the reason deliberates ***intentionality*** from all involved parties; we are going to do well and doing well by managing our risk well; so that was the fundamental reason. It was not only reputation or money. It was about doing things right. Address any risks with delay or schedule to the recovery programme. It was about doing things right to the business, and the people, which was always the focus of ***the media, the politicians and the community.***

Participant P23 clarified the importance of actual interrelationship between the public and the private organisations in recovery projects, because public organisations are not able to deliver that volume of work by themselves. He thought that the key is to have these ***relationships pre-disaster*** and keep the ***communication lines*** as fluid and quick as possible. The scenario with ***bureaucracy***, the slower of response and getting an answer should not be an option in recovery projects, as the power to give quick ***decision*** is essential. Early on in the emergency period and the beginning of the recovery programme, it was more about getting things done and that went really well inside SCIRT, clients gave the permission to the private companies to go over and do a quick response, but as soon as panic is over, and things settled down, things start to slow down where the bureaucracy appeared again.

Participant added SCIRT was there to not just ***fix the infrastructure*** after the disaster, but to make it ***more resilient in the future*** and that is what SCIRT has added in terms of the repair mechanism, but there again public consultation and other views potentially got on the way of that. It is up to the governess to mitigate this risk, also drive the endorse the reason behind implementing the risk management in post-disaster which could be profit, long-term profit, immediate financial impact, the wellbeing for the staff to be maintained, and ***social responsibility***.

- **Procurement approach and integrated management approach**

Participant P22 explained in ***SCIRT procurement approach, the client took most of the risk than the contractor. The reason is to secure the resources for the recovery and build the trust with the delivery teams.***

Participant P25 explained after disaster, work is more about the recovery not the continuity of work. In the beginning of the disaster, the public organisation felt like they are under control with it in the beginning of the disaster while the earthquake damage was not that huge after the first earthquake in September. The first hit was 15% to 20 % of the main hit in February, the response by the council was organised well but after the main earthquake, the client and the steering group understood that this volume of work cannot be managed just by public organisation that is where the private organisations came to the picture.

The government considered and came back with the proposal of SCIRT. It was difficult question because people couldn't handle the truth. ***Private company responded to the public***. The private company understood the magnitude of it and SCIRT with the alliance model was created by the government and was very successful. The alliance procurement model was the choice as there was massive and ***big scale*** of work and the ***scope was unknown***. The scope has been retained to be flexible with the budget. It took around 18 months to handle this magnitude and to ***check the damage***.

Participant P26 stated that SCIRT is because of the earthquake and to ***recover the infrastructure***, and basically, SCIRT has been created to manage the risk of resources and price escalation. SCIRT alliance secured all ***the resources***. The government was afraid that the boom in the construction market is coming, the builders and construction companies would chase where the money is. Council and the client tried to ***secure the resources before the prices go up*** and that was one of the critical risks. They come up with the arrangement and they did it when there are no contractors around to committee to recovery within agreed price and where the cost and the participation are locked in. It is a smart way to secure the resources needed for work to be done and avoid the ***cost goes out of control***.

Participant added also the ***political involvement was high*** due to the involvement of insurance. The insurance companies started to pay hundreds of millions, and therefore, they started to fight back, and the money not secured yet which caused challenges in the beginning of the recovery procedure. These are the ***strategic level risks***. The big risk here is to get all the work done in a reasonable price. The government done it when everybody was desperate for work, so it had the upper hand, and it locked all them in to this arrangement called SCIRT. In addition, the risk here was to run alliance to the desired efficiently and to deliver the objectives in a reasonable time (5 years) and deliver the job in a reasonable price and the community feels that SCIRT arrangement has been successful. The key to such successful arrangement is the good leadership and management towards teamwork to achieve the desired successful story.

Figure E.1 shows the attributes have been identified as drivers of establishing the context stage in PDRM using NVivo software.

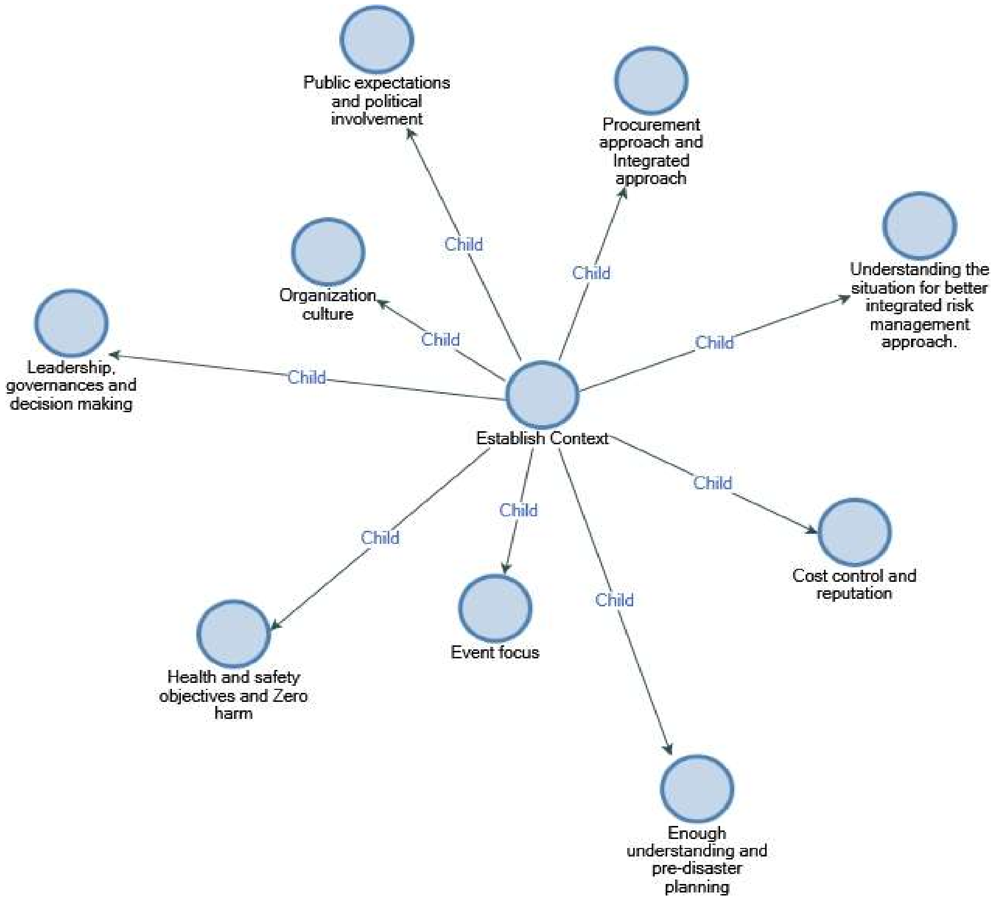


Figure E.1: Node map to establish context using NVivo software.

➢ *2 Risk assessment*

a) Risk identification

- ***Bigger scale, emergency works, quick response, and risk Prioritisation***

Participant P19 stated that it back to scaling and the ability to ***scale up***. Traditional risk management will involve multiple moderation sessions to identify different risks and to evaluate them where in an ***emergency situation***, we have to instantly be able to ***fast evaluate and work in much more frantic base*** and ***identify what the critical risks*** are and do it first before we get distracted with other risks that can occurred or eventuated.

Participant P3 said the real challenge in identifying risk in recovery projects is getting across ***what is real risk*** not waiting until it happens. But the identification is not that good. Straight after the event people doing ***emergency works***, they just go and wrap it. They don't think so much about if they are going to hit a pipe or a cable, they just want to get it done because of time and financial constraints. Therefore, there should be ***fast track risk procedures*** from identification to treatment.

Participant P11 stated looking through risk identification inside SCIRT, the programme risks have been identified better than the ***project risks***. The reason behind that is the experience factor, the people who looked at the ***programme risks*** had lot of experience, while you go to project risks you are talking about ***less experience staff*** due to lack of resources after the disaster against the huge volume of work to be done.

- ***Integration between levels***

Participant P4 stated there are challenges in risk identification between levels in recovery project, for example, what the designer takes into consider is different from what is onsite. There is no much of ***connection between design risks and onsite risks.*** There is ***Early Contractor Involvement (ECI) procedure***, but with less influence from delivery teams because of the ego, construction business could be described as ego centralised. Also***, the less experience staff, and the unique situation***. Moreover, ***risk management in recovery projects need to be more practical and applicable***.

- ***Clear fast track procedure***

Participant P21 explained that clearer fast track procedure is important in recovery projects with enough ***review processes***. For example, it is important that designers develop the risk register and design to mitigate these risks or avoid them when the design completed and add the cost to it. Then that should be reviewed by the contractor in ***Early Contractor Involvement (ECI) stage***. The delivery team should have major involvement to the design face ***to address the constructability*** especially most of the project lifecycle are concurrent activities. Then estimators will review it and put some provisions. However, the risks need to be understood and quantified by all levels. Then when the project allocated to delivery team, the contractor affectively will pick up the risk register and become as a start pointing to the risk management in his project. Contractor will add to the risk and regularly update and reviewed minimum once a month. If risks have not been eventuated, then the cost impact will be a zero.

- ***Different risk profile***

Participant P14 stated that risk profile in recovery projects is different from BAU. For example, in SCIRT risks included ***Liquefaction***, ***low density ground, levels and the survey may different*** due to the earthquakes. However, the major issue with risk identification in recovery projects in how to quantify the risk with undefined scope. Many risks in the risk register ***could not be quantified***. Like ***communications and public risks***. It is too big, and complex is we don't have enough people. ***How community feel***? We ***cannot quantify the risk inside the project***. We need to have ***skilled people*** ***to identify the risks and quantify them***; people with similar experience in all levels client, SCIRT and project team.

Participant P18 illustrated in project level, we need to ***improve foreseen some of the issues*** for better risks identification. That could be done with more investigations.

- ***Different working environment, high stress level***

Participant P23 stated that risk assessment in recovery projects is very much commercial and safety oriented as there could be another event or ***the environment people are operating on not BAU***. This added ***stress to the people*** working on the recovery. Moreover, there are ***business risks*** in terms that ***companies growing very fast and cannot handle the huge amount of work.*** People find it very tough. There is ***quality risk*** in terms of not having the ***quality requirement upfront***. The quality specifications have been developed over number of years after disaster, so you don't know what was expected from there. The share volume of work in short period there is risk around quality there but SCIRT addressed that very well. But if there was ***pre-disaster risk management planning*** and these risks have been addressed before the disaster, then we would have the template to follow rather than ***wasting time creating process around there***.

- ***Event driven risks***

Participant P15 mentioned that the risk identification is event focus in recovery projects. For example, the high risks could include ***earthworks***, and ***aftershocks*** still a high risk. The water ground is high risk, because the ***groundwater map has changed after a disaster***.

Participant P16 mentioned that unknown ground conditions, water table changed, and ***availability of resources*** are the highest risks for the programme. However, the opportunity is that there are lots of similar risks between projects in the recovery programme. For example, traffic management; we have this risk in every project in Christchurch. It could be managed by ***sharing knowledge between teams***.

Participant P21 illustrated that typical risks in recovery projects are ***ground water***, over pumping, ***ground support with deep excavation***, ***communication*** type risks, local residence perhaps don't want work near, and ***traffic management*** where you make diversion and cause damage to the local roads because of the ***traffic loads then we end up destroying existing roads*** and network because of the heavy traffic.

- ***Wider exposure***

Participant P18 stated that risk identification in recovery projects includes additional risks, such as the ***higher-level risks including strategic, political and community risks*** because of the ***wider exposure***, like here 300000:400000 people in Christchurch.

Participant P20 mentioned that risks in recovery projects are not alike as ordinary business, some of them may look alike. Such as resources, ***in a post-disaster situation, just we have challenge from everywhere. The greatest challenge is the people to understand the volume of the situation we are facing***. It takes a lot of time to work out.

b) Risk analysis

- ***Risk understanding***

Participant P11 stated that risk analysis, is always a challenge as it is more into ***risk understanding***, how the people understand the risk, not just to put numbers against the risk but to understand the risk and the impact, which is a challenge in recovery projects, as the scope is not clear, and phases happen concurrently.

Participant P19 specified that in BAU, people are usually underestimating the effect of the risk because of the very low probability of it occurring such as an earthquake, ***people underestimate the risk*** on their lives. However, ***after the disaster, it is the other way around, the risk has occurred*** and overstates the probability then people think it will not happen again, but aftershocks come. People get ***confused about the impact and risks*** all the time, the probability of the occurrence and the actual impact of the occurrence in a case of a major earthquake, and they flip around, and they go back to BAU which is not ideal, ***risks in recovery projects could be described as continues risks***. We did very well risk identification; however, understanding the risk could be done better. For example, the pipe lining, the rework was bigger than expectation due to lack of experience and change in specifications.

c) Risk evaluation

- ***Risks hard to quantify***

Participant P6 explained the risk evaluation process should take into the ***expectations from public are quicker*** and the ***public being destructive***. There is a potential to not get it all right, ***miss something***, so that it is a risk on itself, because of the ***volume of work*** ***and the timeframe and the incomplete design.***

Participant P14 explained that estimators' added risks and added values to ***allow for things going wrong, however, it must be things that could be quantify.*** Like safety risks, you cannot value these risks, so all could be done is to change the scope. The major difference is ***how to quantify things*** and what is the likelihood in post-disaster if something going wrong. In terms of likelihood, is it going to affect the cost by 5% or 10%, is it have no cost value, but just time, all these questions need to be answered.

Participant P15 explained in a post-disaster, the greatest challenge is how to calculate and ***estimate the cost of the risk***.

Participant P19 illustrated the difficulty to get the programme risks quantified. In such disaster, we have budget we do not want to exceed. How we can spread it across the projects, for example, SCIRT programme contains over 700 projects; ***it is very difficult to figure risks in each single item***. What is identified as risk and what is not identified? The other things people are good in identify risks in $ terms, but in terms of safety risks, or schedule risks, it is hard for them. Therefore, they just go for percentage, which is a challenge in the risk evaluation.

- ***Risk Prioritisation***

Participant P11 explained that risk evaluation in recovery project is difficult, because it need commitment, ***people to understand what is acceptable and what is not***. Most people struggle with that and because risks intend to be ranked comparatively, it is important to prioritise risks, what are ***our top ten risks***.

- ***Lessons learned from previous projects in the same programme and feedback loop***

Participant P21 explained in lot of projects with whatever reasons the estimator may allowed something for risk. Here is one party believe that this allowance is enough. Some people will say if we need the job then we need to live with the risks and not allow for any to get the job with competitive price and then do get the job and if these risks may be removed and replaced with new risks. ***It is***

important to know what the driver risks in your project are then the cost could be controlled. It is important to communicate all these risks to the project team to be fully aware of these risks and not to be ignored. If project team ignored the risks and generally these jobs not gone well. ***Understanding the risks*** and try to manage to avoid or try to make the risks never occur. Regular review of the risks is vital; most people would find risks never occur. The financial benefit will be quite good result. Generally, any job with people, it will have a risk, because ***people are different in skills***.

Figure E.2 represents the node and the child node using NVivo software of risk assessment concept.

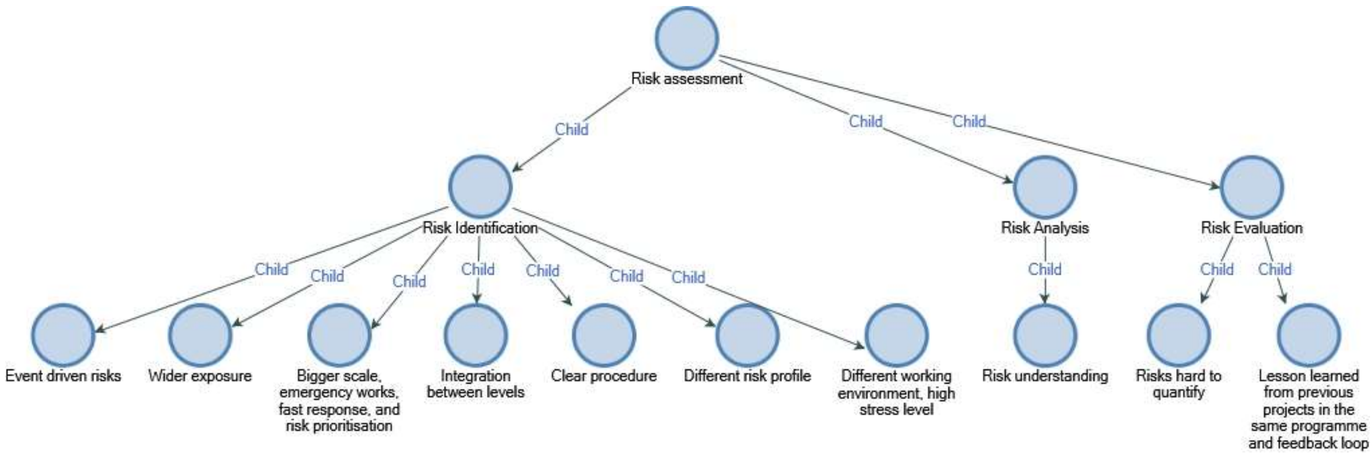


Figure E.2: Node map of risk assessment.

➢ *3 Risk treatment*

- **Critical thinking**

Participant P10 stated in post-earthquake, the people focus is in the risk treatment, and they forget about ***the evaluation after the treatment*** due to time and money constraints. People may understand how to mitigate them, but the evaluation of it is enough treatment or not is not ideal. For example, when we put scaffolding on river for supporting retaining wall, have to pull it out because of the rain and water level increased. Evaluation what is going to happen, you know that the treatment is to pull it out however, the assessment is why you put it in first place if there is a risk***, it is type of critical thinking***.

- **Follow up, culture and mentality**

Participant P11 stated that risk treatment in recovery projects is the hardest end; it is easy to set in a room and identify the risks and talk about everything in theory and concept. To put all that in action, it required lots of other people involvement required ***follow up***. That is hard to do. The other problem is to have ***earthquake revisions***, along the way people thinking about disaster it will not happen, and if it happened, it will be stand-alone and onetime thing. ***It depends on the type of the disaster, but after disaster people always has to allow for aftershocks.*** It is more about ***mentality***. Something went wrong; people always focus of what is going to happen rather than focus in something that may happen. For example; cost forecast, the risk of having to do rework after doing the CCTV in pipe lining project. When delivery teams have not done allow for this risk in their forecast to complete because they thought they are going to get the job right from first trial and no ***rework*** needed. It is part of ***culture***, part of it people don't have any intention to have an accident here and there that is why they not allow for it, but it happened. ***We intend to do everything right, and we forgot to allow for rework.*** It is adopting the right approach to keep in top of the risks.

- **Cost control**

Participant P14 illustrated that risk treatment is connected to ***cost control***, and it is always helpful to checked whatever have been allowed in TOC, then check how much of risk allocation have been used and how many risks happened.

Participant P19 stated that the risk treatment in recovery project vary depend on several aspects such as the ***location, the priority, the cost*** and schedule.

- **Proactive approach**

Participant P24 explained that the risk assessment is hard especially in the beginning of the project in recovery projects because of the unique situation and the more we go through the project life, the better to understand the risks especially when taking the lessons learnt from previous projects. Nevertheless, the evaluation and the treatment of risk should be as good as the assessment of risk. The treatment of risk is a fundamental project management practice. The people in the ground should be ***proactive***, working on the risks, reflect that into the project cash flow, and keep it as dynamic as possible.

Figure E.3 represents the node and the child node using NVivo software of risk treatment concept.

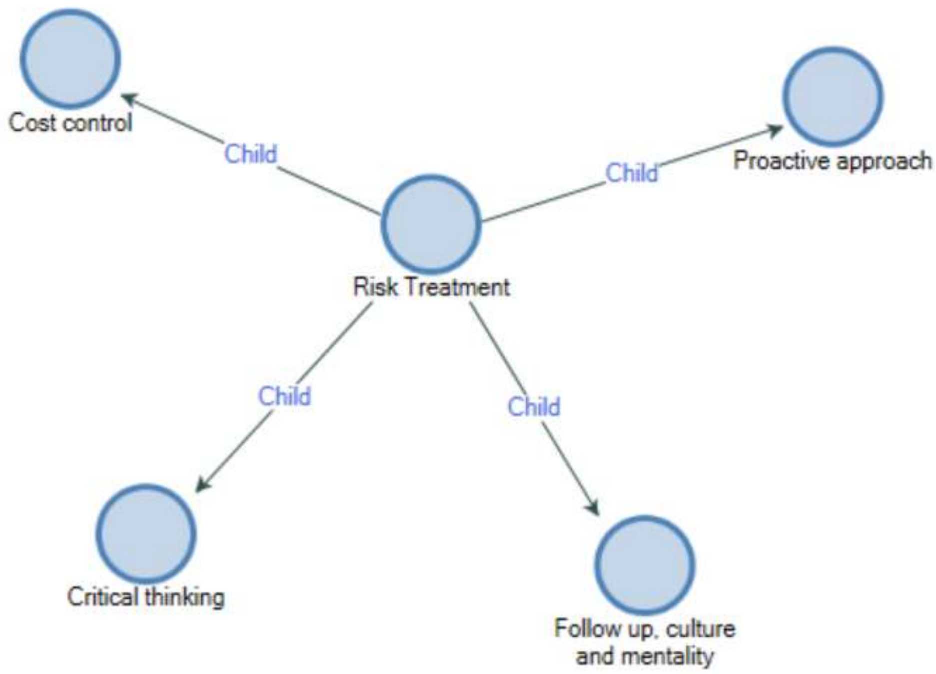


Figure E.3: Node map of risk treatment.

➢ *4 Monitor and controlling*

- **External audit**

Participant P2 believed that independent external review is recommended in recovery projects because it opens the channels of ***sharing the ideas*** from other post-disaster organisations to make sure we are thinking about the things we should think about especially when ***the scope of work is not fully defined yet***. However, when the scope of work is fully defined, it could be reduced unless the client wants to ensure that the risks have been managed probably and correctly.

Participant P5 believed that even best care about the risks who owns it, but external audit ***gives more ideas***. Moreover, external audit is important especially with ***unskilled staff and unique situation***.

Participant P9 thought that using external audit and reviewer is very good idea, it gives the risk management process more ***professional and make it more open to ideas.***

Participant P12 believed that external audit is good in recovery projects as it can be used to confirm ***the best practice of risk management and ensure that people are following the process***.

Participant P13 argued that independent review is the better approach in recovery projects as it is important to ***be challenged in risk management*** to come over all risk and that should be frequency and to be measurable.

Participant P14 stated that even ***it is hard to quantify risks in recovery projects***; we need to have people who know what and how to do that and they need to be involved in ***early stages***, that is one of the main benefits of external reviewers. The benefits of external review have to be measured as it depends on if the result worthwhile or not.

Participant P18 recommended external review as collective effort is better than one or two people as it provides ***more opinions, more heads***. However, ***benefits of external review should be weighed against the cost*** to ***justify the cost*** of it.

Participant P17 believed it should be third party, even from the same company but independent but better to be totally independent from outside the company, ***with external review new ideas, and better support of best practices.***

Participant P23 argued it is more about the people who are facing the risk, if they are good enough then no need of having external audit. But the benefit of external audit would be to help in reviewing ***with more eyes, the better the result***. It is needed to be done at the start of the programme to put the people on the right track with high frequency in the beginning and as time goes on it should be decreased.

Participant P24 stated that external audit if important tool to report the quality of work and procedures to the top management in recovery projects. For example, there is board and CEO in SCIRT, and they need to understand what is going on around them, if things getting better and steady with cash flow like the teams carrying $4 to $5 million of risk allowance that is about 25 million of risk budget, this budget could be used in another project if we are not facing the risks. Delivery teams should hand it back to the programme to do other projects. However, some delivery teams are aiming to keep the money of risk till the end of the project to feel much secured. With this approach, delivery teams are releasing these $25 million now at the end of the programme; we can allocate this money to do 3 or 4 more projects. Manage the risk from programme perspective is making sure the team are only carrying appropriate amount of risk from where we at and is being released as it should be and ***not holding risks money till the end of the projects***. It is cooperative approach of managing risks as the teams are part of this alliance, that is why ***doing programme review of how it be released*** is essential.

- **Internal audit**

Participant P1 argued that if we are talking about overall company risk, probably it is ok for have external audit. From project point of view, after earthquake, it is more practical to go for ***internal audit to save time and money***. For sure, there are good internal resources in each company to audit another area especially in large companies.

Participant P10 argued it is always about the ***biggest improvement*** in both post and pre-disaster. The baggiest issue after an earthquake is the volume of work and the workload go up dramatically which required new staff. Some of these staff promoted to do jobs that may not be competent in and that where the risk lays. Lays a lot on ***the inexperience and unskilled staff*** that is where external audit is important to fill this gap.

For example, SCIRT has done independent audit frequently where independent person took a ***quality assurance*** audit on SCIRT. To make sure it meets ***the best practices***. But when we look to SCIRT contract, it is clearly states that the ***quality assurance is delivery team responsibility and driven by DT***. This arrangement has been followed to avoid any delays due to the time and money constraints and to build the trust between the client and the delivery times that they will do the right thing with internal audit.

Participant P19 stated that for large complex recovery project the ability to upskills and educated an external party with all the ***complexity*** ***to get them up to speed then be able to get a valuable learning from them***, it is quite difficult. That is better to be build inside the structure or the organisation. For example, the external audit for SCIRT was somehow related to the risk management, so the external reviewers come through and looked to the earned value reporting that was risk management tool effectively.

Participant P3 argued that external reviewer should be involved only when ***they have enough experience of what have to be delivered and be familiar with the risks***. For example, because some reviewers are not familiar with the industry or the methodology, they may think it is wrong, however, they just ***not familiar with what we are doing***. ***If you will have external auditors, they need to be familiar with what we are doing*** and that is why it is sometimes better to have internet someone who knows what we are doing. In addition, in a post-disaster, probably we want to ***do things quickly***, ***and then internal audit will be more effective.*** That is because we don't have the time or the money for external review.

Participant P4 thought it depends on the capabilities of project team, if there are ***good people from inside the company*** who really know how to manage risks and quality audit the procedures then internal audit would be the preferred option. However, in post-disaster situation, it is tricky as the staff is new to the market. Also, it depends on the ***type of the disaster*** and the frequency of the disaster. For example, in New Zealand, we can expect earthquakes, floods, but not wars so if we need to manage projects with airstrikes for example, ***we will need external audit for people who have experience about this type of disaster***, but for something already happening most of the time, looking inside would be much better.

Participant P25 thought that ***even external audit could look important in recovery projects but we can over complicate it***. For example, we can get a risk management consultant which will take time and money to produce a massive report however, with the time and money constraints in recovery project, it is hard to implement the outcomes. However, with the internal right people, we can achieve better results and it is the more practical solution in recovery projects. Collective effort of internal people working together on the risks and put together a simple doc and keep the risk register live on a monthly basis and challenge that every six months with internal audit is more practical solution rather than ***external audit for the political purposes***.

Participant P20 stated that in the beginning of SCIRT programme, there was ***risk management process*** independent review. The funders questioned the whole bases of TOCs, model and the risks. Actually, ***it raised the confidence*** in SCIRT hugely. That means partial involvement of external organisation and review is recommended. It doesn't need to be continues review; as better that the project team be responsible of their own risks.

Figure E.4 represents the node and the child node of monitoring and controlling concept using NVivo software.

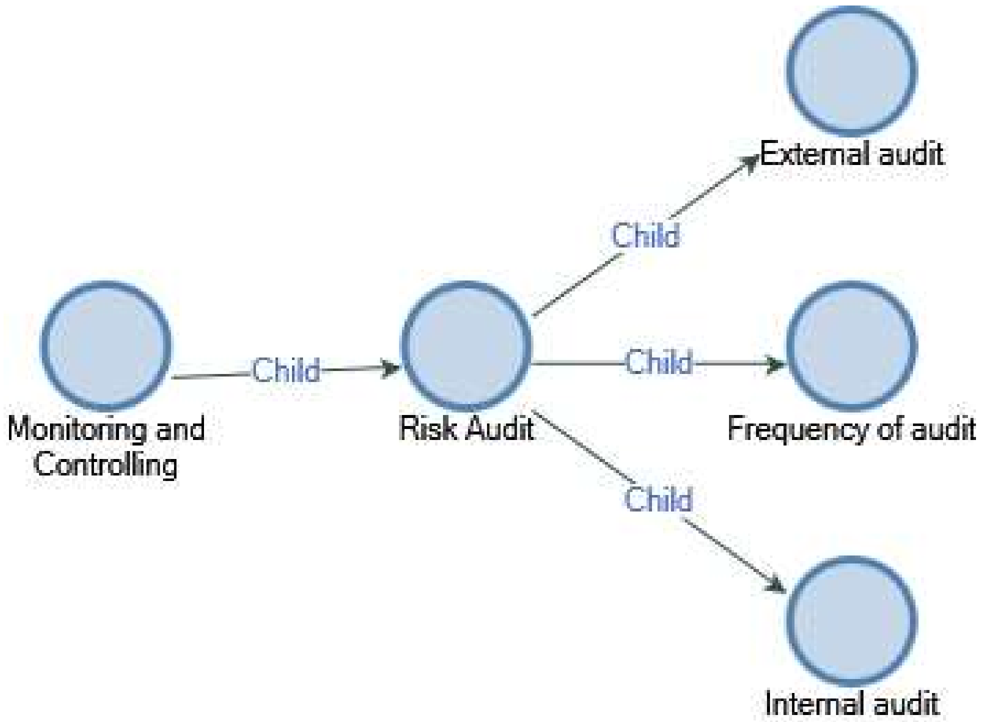


Figure E.4: Node map of monitoring and controlling.

➢ *5 Communications in recovery projects*

- **Cut the regular consultation process**

Participant P24 stated that communication in recovery projects is really different from BAU. For example, in BAU, if we looked to work from ***council*** or with ***community***, there is a consultation process which represents the bureaucracy of the government systems. However, with SCIRT, ***the consultation process didn't exist***, and that is important particularly in disaster recovery to be able to hit the ground running, keep going, and get things complete. This cut in process helped in the acceleration of recovery process. However, the consultation process reduces the risk of losing the support of the community, therefore, this cut in procedures need to be backed up with an ***effective communication plan*** especially with the community to avoid any frustration.

- **Aftershock communications**

Participant P1 thought that as long as the ***panic stage*** passed, the communications will be the same with different in scale and context. The communication would be more event focus like about safety risks and the followed risks after the main event such as ***aftershocks or tsunamis*** which required ***more communications.***

- **Avoid conflict**

Participant P17 stated that communication is a key factor in construction industry however, communication in post-disaster more critical. We don't have time, so communication must be more effective, accurate and fast to ***save time and avoid any conflict*** with any parties.

- **Bigger scale**

Participant P3 mentioned that in BAU, communication is quite simple where after a disaster; there are ***a lot of people interested of what we are doing***, such as government, heritage organisations, councils, SCIRT, delivery teams, etc. ***The scale is quite big***.

Participant P15 mentioned that communication has been increased dramatically after disaster as there were ***more channels***.

- **Front head communications**

Participant P18 explained the need of clearer ***communication*** and ideal identification of the ***strategic risks*** and ***agreed procedure*** of how to manage these risks in higher level. One of the key risks in the delivery phase of recovery projects, there was different message have been given. Something SCIRT has done well is in managing the communication well and keeping the community informed of the volume of work. SCIRT programme has been one of the best practices of good communications and ***lessons learnt***. Because of the competitive market in BAU, this type of ***front head communication*** is missing.

- **Intentionality and meeting public expectation**

Participant P20 explained the important of ***intentionality*** in communication in recovery projects which give the opportunity to overcome the barriers of communications. All involved parties need to think the same way as the ***uncertainty increased*** after disaster this makes the communication more important than usual.

Participant P7 mentioned that one of the biggest challenges in communications in SCIRT is ***meeting the expectation of the public***. For example, there have been initial statements made by politicians that with in a 10 years period, the city will be totally rebuild, some of these statements have no base to make. If we checked similar recovery stories, Napier took 20 years to rebuild, part of Los Anglos after their big earthquake in early 90s took 20 years to rebuild. There was no evidence on that Christchurch as a city could be fully recovered in 10 years. But politicians, ***under the pressure of public and the media,*** put these comments and it stick and be in people minds. ***Perhaps they will be very unpopular*** because of ***public pressure after the earthquake***.

Participant P5 explained that people would like to know what is happening in their surroundings. Also, ***deliver one constant message*** especially in promises and what the people expect because if the promises changes, people lose the faith on the recovery team.

Participant P18 thought that one of the issues in recovery programme is the number of organisations involved because of the ***large programme of work***. For example, SCIRT contains 5 main delivery teams, how to maintain ***a constant message with so many hands on the pie.*** In addition, the client representative have their own drivers, as well as the drivers inside SCIRT, such as, Crowns and Christchurch City Council (CCC); the information that they are giving out, in terms of risk information, it is hard to maintain the constant of information and procedure and be able to manage the risk, ***it is hard with so many different organisations involved to maintain constant approach***. We need to have a common path of risk management in recovery projects, it is hard with so many inputs but it is essential ***to have one message***. For example, SCIRT mission statement, creating resilient infrastructure for people of Christchurch, the update of this mission statement to reflect the reality is a requirement. It is now creating a level of service approach in the infrastructure which should be communicated to the community and people. ***The reality no budget for that, so, there is a balance, so we need one message and this message be relevant to what we are really delivering and*** if that changes, we should change the message. We need to be consistent with that message. Also, internally, staffs need one message, why we are here and what exactly we are delivering? For example, patch and dispatch instead of renewing. If the bar has been lowered, the message should be communicated internally and externally to avoid any frustration.

- **Irritated public communications**

Participant P4 thought in recovery projects, ***people would like to know what is happening in their surroundings.*** Therefore, communication channels with public need to include the emotional part of the public because ***they went through a lot*** and the message need to be clear that what is happening around them is to make their life easier. Failing to deliver this message could increase the irritation and may cause delays. In recovery period, construction companies are very desirable because of the recovery process however, ***after the recovery; the community doesn't want companies around because of the distraction the company made***. People just want their normal life back.

Participant P11 explained that ***communication is more difficult in post-disaster environment***. It is particular difficult not because of the physical systems are disrupted, people roles are changed, and they just live with it. ***The routine ways of communications have changed, all the communications are based on post-disaster psychology***. The communications are very difficult to get very consistent. Studies showed people attitude changed after disaster like earthquakes in New Zealand or bush fire in Australia. People are shocked, and ***they stay in stress which impact the human mind and make it less receipted the routine communications***, ***or ever not receptive at all***. It is like people just went to automotive mood of intense which will need more effort in communication. It is a very serious risk need to take into consider for more ***effectively communicate***.

- **Language barriers**

Participant P2 noticed that the ***language barriers*** are a key factor affecting communication in recovery projects. People come from different cultures, different backgrounds with different accents to help in the recovery after the earthquake due to the resource shortage. Probably 90% of the staff is from other ethnic origins. So, ***communication in just the language is different.*** The language barriers need to be considered in recovery communication as the scale of the work open the gate for the world to come and help and people need to clearly understand the risks and the procedures to avoid any delays or errors.

- **Fast communications**

Participant P19 stated that communication is hugely important in recovery projects and one of the biggest advantages is that ***all SCIRT team was in the same building.*** Most of SCIRT communications was face to face. Effectively, SCIRT building was built in 6 months and 300 people was hired as a part of the recovery relieves as a one location and encourage effective communication. Moreover, all the teams have access to each other's with ***very effective information system***. ***SCIRT***

was built very quickly and was concentrating on shifting culture behaviour and communication was one of the key items that organisations perform.

So, communications before BAU and post-disaster are different. In post-disaster simply, there is no time; ***quick response, answers and decision are important factor in recovery projects***, which make face to face the preferred option. ***You don't have the luxury of time to get things done as you have in BAU.***

Participant P21 stated that it is important in recovery projects to do services as quickly as possible and cost effectively. Therefore, SCIRT assigned five teams with huge amount of expertise to save time and money. ***Putting the team in one building is reducing the risk of communication priors and faster decision making*** to support a quicker response which was highlighted as high risk that need to be avoided with five contractors to execute the work.

Figure E.5 represents the node and the child node of communications concept using NVivo software.

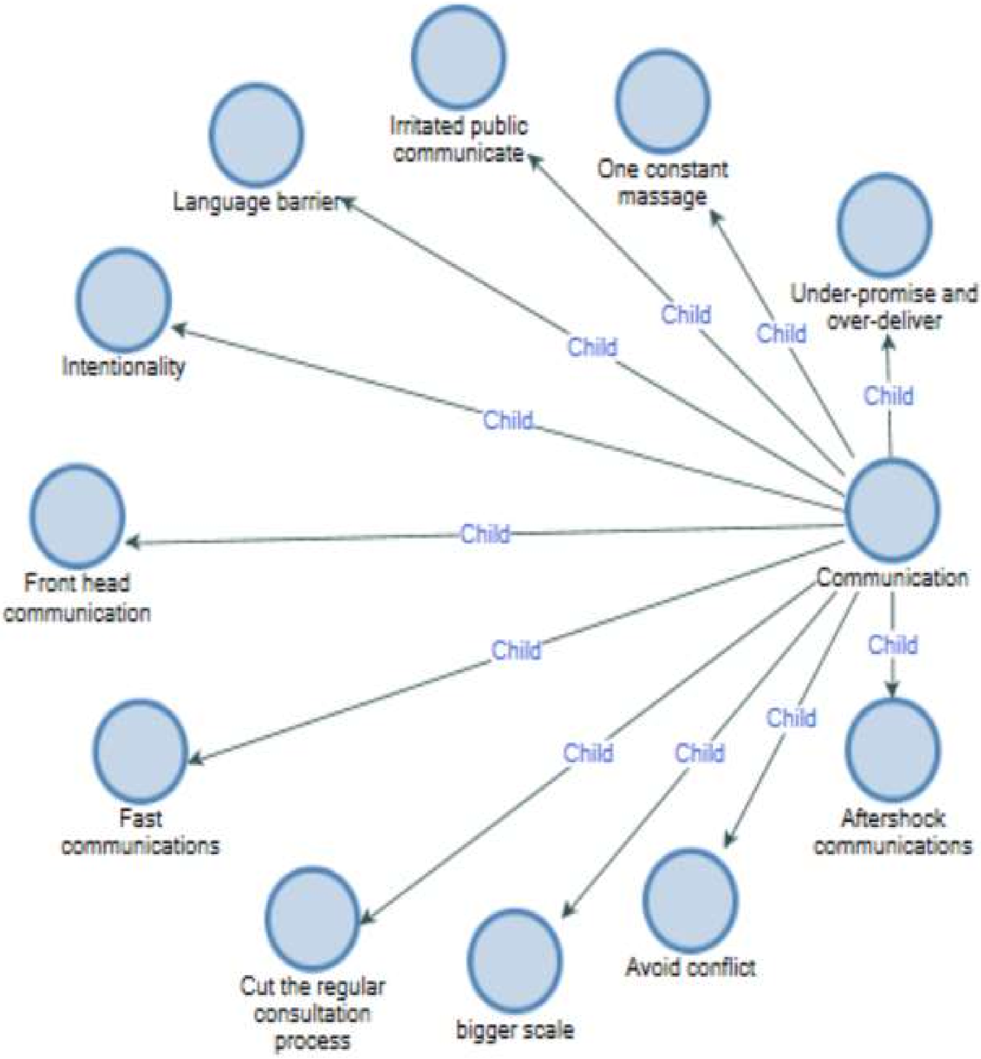


Figure E.5: Node map of communications in recovery projects.

➢ *6 Resources in recovery projects*

- **Resources availability**

Participant P2 stated that resource availability in recovery projects is depending on the disaster location and ***it is a massive problem after disaster.*** In SCIRT for example, the risk of securing the materials such as aggregates were pretty safe because ***we are setting over a big quarry*** actually, but you still need ***consent*** so really maybe it ***processes*** that can affect the risk management in recovery projects.

Participant P3 mentioned that in post-disaster, you normally are ***looking hard for resources***; you put your hand in what you can find. Machinery, excavators, ***there is lack of resources***. You just need to get it done. The programme will have lot of risks in a post-disaster, just ***because of that time factor***. You will be hiring anyone before you may go to the same process that you may do in BAU. ***You even don't look in deep of their previous history*** ***and safety records*** which could affect the project quality.

Participant P4 explained the type of the disaster is affecting the resource availability. For example, human made disasters, like airstrikes is completely different from earthquake. Private organisations here should increase risk of natural changes, the geography; public organisations should know ***fewer resources will be available***. Prices will probably go up so private need to assist the risk more from different view where the public need to increase the resources demand and probably more money involved. After disaster, everybody will rush to the new open opportunities areas. However, ***you may have physical resources but you don't have human resources***. The human resources are lacking because nobody want to be in disaster area.

Participant P5 mentioned that ***direct after the earthquake there was a huge movement which affects the resources availability and continuous resources drain***. There was a ***huge lack of resources*** after the disaster.

Participant P9 stated after disaster, ***we don't have enough resources***; it was a problem which affected the risk performance.

Participant P12 stated that the resource availability increased your risks in recovery project. ***It is planning for the unknown***, ***are these resources going to be available***.

Participant P13 stated in SCIRT programme, it was substantial issues because ***the key resources are not there***. Also, you need to look more into innovations in design; you can look different products, or ways of doing it to reduce the risks.

Participant P14 mentioned that after disaster, there is ***huge lack of resources***. For example, pipe lining contractors in SCIRT programme, they used to be 5 companies but they dropped to two due to lack of competency which put the programme in schedule and financial risks because there are not enough resources.

Participant P15 stated that the lack of resources in recovery projects has direct effect on the ***risk performance because it will drop the standards and the quality for work done and will have more risks to deal with***.

Participant P17 stated that resource availability ***is so critical and high risk in recovery projects, because after disaster, all the resources moved and the volume of work would need bigger number.***

Participant P25 believed that that after disaster, ***you need large amount of people***. People leaving, part of existing team wants to leave. For example, in Christchurch, there was already good engineering population but after the earthquake most of them are gone. However, the rest of the country was keen to come to Christchurch market, even the rest of the world, in terms of ***attacking engineers and crews*** to come and rebuild the city which make the situation much better. ***If there was another open market, it would be a bit of a challenge***, as the resources would have another destination to go. Also, after disaster, the people mental health and emotional involvement due to the high stresses after disaster should be considered and SCIRT was good example of successfully dealing with this issue.

- **Resources Prioritisation**

Participants P1 illustrated the importance of using the right people and ***resource Prioritisation*** in recovery projects for effective risk management.

Participant P19 explained that ***One of SCIRT priorities and the reason behind creating SCIRT identify the risks and take fast actions like for resources, is to secure resources. The continuity of work by centralised planning***.

- **Resources capabilities**

Participant P6 mentioned that knowing the ***team capabilities in disaster time is crucial***. For example, if disaster happened, you know who you can depend on and who not. Before the asset owner asked, we knew what the risks are and discussed how to mitigation them. ***Get the right people in the right place***. With aftershock, they are happy to stay, a bit of shacking didn't worry them, they concern about it, but they didn't panic. That is the difference, some people in these situations, creates more problems for you than they can solve. Therefore, it is important to know your staff capabilities.

- **Staff retention**

Participant P13 mentioned that ***Staff retention*** is a great risk in recovery projects as they used the system and have been trained then they go to work in better places.

- **Staff wellbeing**

Participant P10 mentioned that the biggest risk is the people, the people come to work for long hours a day, some of them marriage have been broken up or lost their loved ones due to the disaster, how we manage that risk is important. We ***should think about the people enough***. We are quite good at looking to the staff on front of us but we r not good in looking to what influence the staff which extremely important***. It is important to observe the people and check their needs to get what you expected from them.***

- **Work under pressure**

Participant P5 explained it is really more complicated after disaster regarding the resources. Work need to be delivered using ***staff under pressure***, as a successful recovery project manager you need to ease that and find ways to make it easy for everyone.

Participant P23 thought with post-disaster situation, it pulls in lots of ***inexperienced staff*** to a position they may not familiar with and ***put pressure on them***. That is why they will need more training and communication all the way through the programme to ensure that risks have been managed well.

- **Inexperienced staff**

Participant P1 stated that there is a ***difficulty to get professional staff*** after a disaster; everybody is running out leaving everything behind seeking safer place.

Participant P9 explained how the construction market changed after a disaster. Taking SCIRT as example, due to ***lack of resources***, some project managers come from different backgrounds not related to construction industry and they are managing construction projects. Even if some of them have construction background, they don't have the enough experience about roading projects or infrastructure. That what happened in Christchurch after the disaster, ***lots of resources with not related experiences*** which affect the overall performance.

Participant P10 illustrated that the expansion of work required massive number of resources, caused a lot of issues, you got Forman who is now supervisor, supervisor who now become ***a project manager with less experience***, ***because of no resources***. For example, when we put management plans for a project we will need the inputs from an expert project manager. But due to lack of experience, the inputs of project manager would be not good enough which increase the risks in recovery projects.

Figure E.6 represents the node and the child node of resources concept using NVivo software.

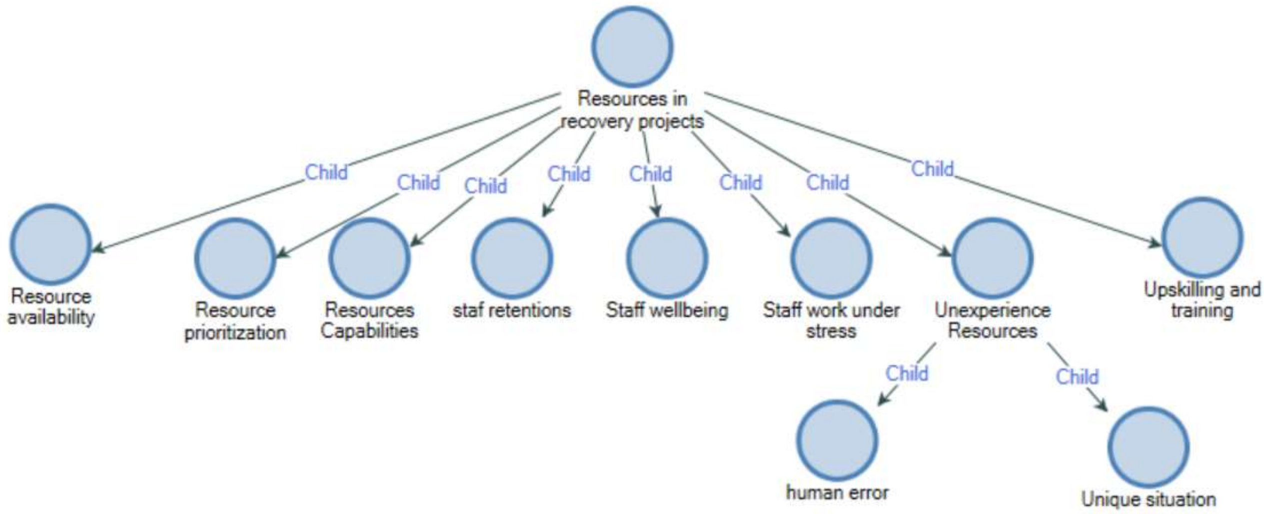


Figure E.6: Node map of resources in recovery projects.

➢ *7 Culture after disaster*

- **Business culture**

Participant P6 stated that each organisation has their own culture, and companies always argue that they have differences between them, because their culture is better. If the ***culture*** is right, there is a ***trust*** between the management tier, all the people ***feels as being part of the business*** and they are ***aligned with the business values***; then the likelihood of risk occurring mitigated by resources or the staff is going to be less. They care about the project and they ***take ownership of the risk***. They take ownership of any incident. That includes all the risks from health and safety, financial, quality, time, resources, and training. It is ***the culture within the business*** ***that will drive the great outcomes in recovery projects***.

- **Organisational culture**

Participant P1 stated there is ***different between the companies*** of the ways they look to things commercially but culture wise, everybody knows what they should do. Like safety culture to keep people safe in recovery projects which is driven by SCIRT.

Participant P2 thought the ***company culture was different*** between the five delivery teams in SCIRT but the alliance behaviour mitigated that. To remove surprises, to have more accurate financial forecasting and make sure people are safe and it was a good management to see whatever will be in your road and put measures in place to figure out how to mitigate it, the alliance culture.

Participant P3 mentioned that companies have to ***follow the safety regulations and the rules***, but some companies are better than another however, the alliance culture covered that. In the SCIRT model, every one come with own way of managing risk and try to improve, some companies just followed the rules, some others just let the guys come up with their own thing. ***I mean every company is different, but rules are rules***.

Participant P15 mentioned that ***each company has its own thinking and mentality***, ***even inside the company between section to section or department to department***, it is different. ***Some culture impact negatives the risk performance***.

- **Public culture**

Participant P5 mentioned that culture is critical in recovery projects in both ways; ***organisational culture and public culture***. Organisational culture is affecting the way delivery teams handling the risks driven by financial gains, and with public culture, you have to find initiative ways to address the ***emotional and media layers*** of conflict.

- **Mixed culture**

Participant P3 stated there are ***so many foreigners they bring their own culture on*** to the recovery which is good.

Participant P4 mentioned that he came from ***completely different culture***, and communication there is different from communication standard in NZ.

Participant P13 mentioned ***in recovery project after disaster, we see things differently as European.***

- **Culture flexibility**

Participant P2 thought the culture has a big impact on the risk management in recovery projects. Looking through the ***alliance culture***, there is need of ***flexibility*** and ***change management***. For example, some ***company's culture*** ***has no boundaries***. If we are in ECI phase, what if we use a different product what if we deal with the community differently. You need to have space for ***innovative and try something different***, ***having rules and challenge these rules***. This is the culture that alliance bought. Something like ***thinking outside the box and dealing with constant change***. Culture has a massive part to bring the team together in recovery project.

Participant P9 stated that risk management in post-disaster is depending on ***the organisation culture***, they need to be ***open for changes*** and ***flexible*** to come over the communication barriers.

- **Culture resistance**

Participant P7 thought the culture in delivery teams are driven from top to bottom, from SCIRT model filtered down to delivery teams. However, ***there was resistance by the individual companies***. For example, some of the companies banded lining probably a year ago, they said this is unacceptable risk, we are stopping it. They were actually lining company; they won't do it because the risk is too high. That is a situation where they gone against the overall risk profile coming down from SCIRT.

- **Let us get it done attitude**

Participant P1 stated that country culture also affecting the overall post-disaster risk management. For example, ***New Zealand kiwi culture*** influenced the risk management in the recovery of Christchurch, the attitude of "***Let us get it done attitude***" It is a New Zealand culture more than company cultures which is the reason of several accidents.

Participant P3 mentioned that straight after the earthquake, the attitude was driven by emergency where its focus was to just get it and get it done and later you will get it better and better in identifying risks. ***You just need to get it done***; your programme will have lot of risks in a post-disaster, ***just because of that time factor***.

Participant P7 stated in post-disaster, the work has to be done very quickly regardless of what the outcome will be. ***Just make it work and get it done***.

Participant P13 mentioned it is good to measure ***risk maturity*** between different identities, different organisations. The performance linked to the company culture and the business. Some ***the***

cultures are stronger than the others and it ***affecting the performance*** driven by ***a can-do attitude***. That is directly after the earthquake when companies got into the work, their style is to get it done.

- **Organisation size**

Participant P17 stated that the ***culture is key point in how to deal with risk***. Big companies have proper procedure and technical manager to manage the risks and you will find small companies have ***different procedure*** of managing risks. For example, technical resources; ***big company culture is different from small companies.*** Maybe this one can deal better with disaster projects than small companies.

- **Customer and market focus**

Participant P18 thought companies are acting different in recovery projects; some have ***customer focus*** and also ***focus in the market***.

Participant P25 mentioned some companies have ***immediate response*** to the people. After ***aftershock earthquakes***, direct crew go home but next day they back to work for help People. ***It is a good sensitivity with customer***, how we can help. How we can do. Resources and structure, how to feed all back to the client, it is important in recovery projects.

Participant P26 stated that the culture is mean "***Do people care***? You may be keen to do a good job but you are missing the main point which is getting top of your programme. You have to get in top of your programme, and then the risk will be easy to manage.

Figure E.7 represents the node and the child node of culture concept using NVivo software.

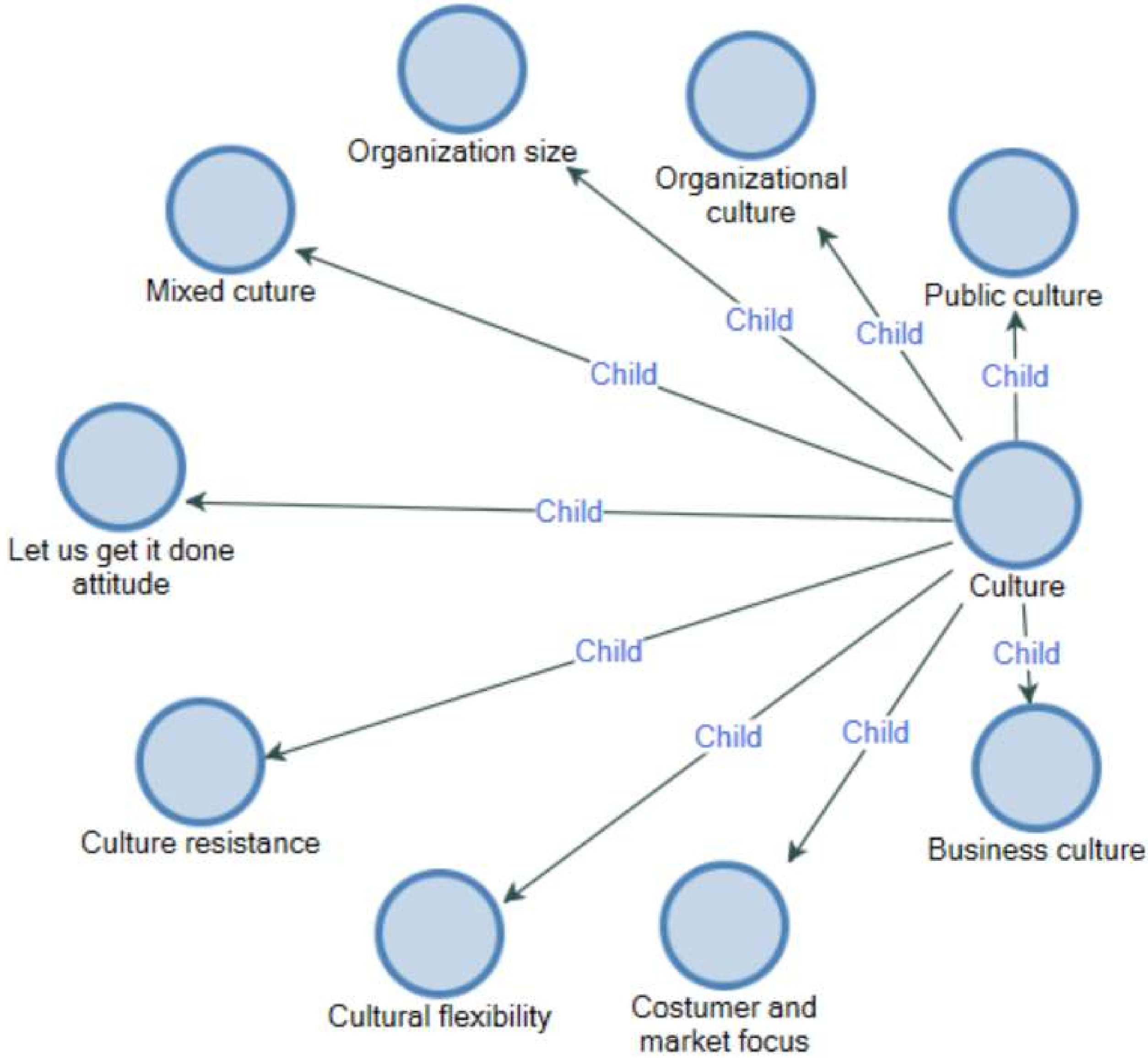


Figure E.7: Node map of culture after disaster.

➢ *8 Trust*

- **Trust between management**

Participant P12 stated that in recovery projects, ***trust connected to the*** ***risk profile***, for example the risks of doing work before having the approval, ***there is no risk in the alliance***, because you do the work and get margin. The beauty of the alliance structure allows the risk to be shared. It is very much depended of the structure. The alliance is about go and do it, you will get what have you paid for it and some margin which was important because of time factor and to recovery quickly. If it is out of SCIRT, it will depend on the contract; it would depend on the relationship with the engineer.

Participant P13 illustrated that due to the trust between the client and the recovery companies, some companies have been there direct after the shock to help with the recovery and take that risk more than the others based on their ***culture and trust to the client***. In SCIRT situation, companies were not in real risk, it was a gain situation. That is why the companies went to get it done.

Participant P23 mentioned that ***trust is a big driver in recovery projects***. We need to have trust which is based in openness between the government and the private companies.

- **Trust in the team**

Participant P6 explained if the ***culture*** is right and there is a ***trust between the management tiers*** and all the people feel as part of the business then likelihood of risk occurring mitigated by resources or the staff is going to be less.

- **Public trust**

Participant P5 stated that ***trust and openness to internal and external stakeholders***, and ***community is important in recovery projects.***

- **Trust issues about forward works**

Participant P1 sated there are normally organisational risks regarding ***forward works*** and what companies and staff will do after the recovery finished. The steering management should have clear strategy around that, because people will start move before the programme end and that may affect the delivery.

Figure E.8 represents the node and the child node of trust concept using NVivo software.

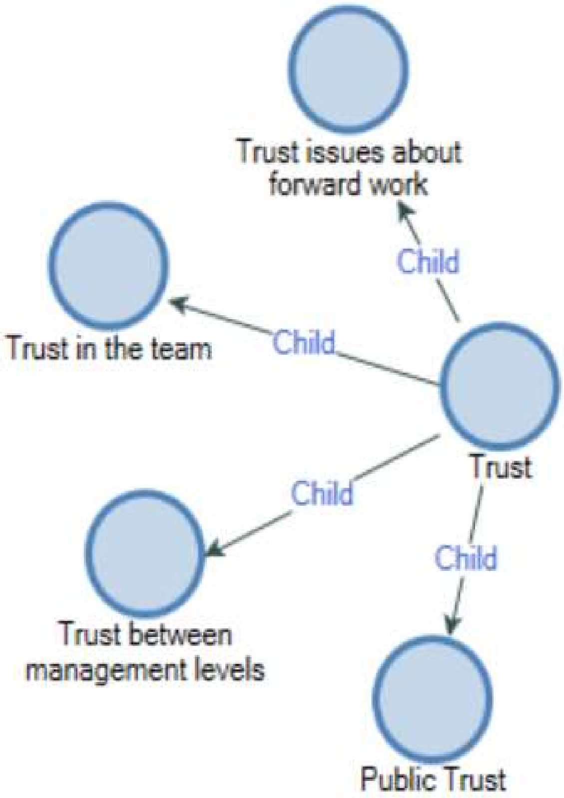


Figure E.8: Node map of trust in recovery projects.

➢ *9 Complexity levels after disaster*

- **Huge number of stakeholders and external involvement**

Participant P6 explained that project prior to a disaster; you follow that normal timelines with typical normal business process and standard project activities. After a disaster, you normally got the ***central government*** involve, ***regional government***, the ***public*** perception to get everything right. It introduces a lot of ***new factors*** that you not normally have in BAU. There are other people involved such as third-party insurance and ***funding issue***.

Participant P21 mentioned that wider range of stakeholders in recovery projects. For example, the client of SCIRT is at the end ***the people of Christchurch***. Three organisations are acting on their behalf; ***NZTA, City Council, and CERA***.

Participant P25 believed that in recovery projects, there is lots of ***external involvement*** such as ***public opinions*** which directly impact the ***risk profile***.

- **Complex social impact**

Participant P1 illustrated the complexity increase in recovery project due to ***social impacts***. Some people scarified themselves to help the city where others were had ***negative impact such as*** stealing after the earthquake.

Participant P14 explained that after Christchurch earthquakes disaster, a lot of people from effected area dropped everything and moved, about 30,000 around the country, ***people lost their jobs***; they have to move on and find another job. However, lots of people also come to Christchurch seeking opportunities from all-over New Zealand and from around the world to reconstruct the city. However, we need to have people with decent skills sets which we didn't need in BAU. Other thing, people have changed, ***the type of people in Christchurch have changed***. They change their jobs. There are no buildings to back to. ***Some business changed***. ***It is so complicated*** environment after disaster.

Participant P20 illustrated in a post-disaster situation, ***the impact in society is huge***. You are really dealing with ***different society after disaster***. SCIRT didn't recognise it that much in the start. SCIRT did a survey around community, 80 to 90% were agreed and happy with the work done. SCIRT recognised the benefit of working with the community. They need to feel the support after the disaster. Moreover, ***the people attitude has changed overtime***, in the beginning of the project, they want you to come and help. However, they get tired and near the end of the project they just want companies to finish fast and get out of the road. Because ***people getting tired of repairs***.

In addition, the economic factors are important as well. People recognised that. People need feeding and machines need maintain which affecting positive the economy. It is a secondary effect on the community and the economic.

- **Different variables**

Participant P10 thought that what might be misunderstood in the back end of recovery, ***that there are so many other risks we haven't thought off because of there is so much other changes and***

so many different variables and different experiences that people have. For examples in one recovery project, we have a group that looked after people, we had September earthquake, was significant earthquake, that affect the garage area but it wasn't that big in other areas. It was a long rolling one not sharp; five days later we had a very sharp one. Close to Christchurch and the people couldn't really react. Because they are quit empathetic people, it hurt them really hard. And they went off and they said no need to stay for another day because they were humans and unable to separate that and they lost. If you look at ***civil defence recovery***, ***the risk that set around that was not fully understood***, ***they have people are ready to help others, but they actually can't help themselves***. Sometimes they are to empathetic and if something keeps happening, they actually will not be able to do what they come for during the planning that they said they will do. It was very surprising that ***they unable to disassociate themselves from what is going on***. ***A lot of them were just a mess and unable to perform the tasks.***

Participant P19 illustrated in post-disaster, ***the risks amplified***, it is the ability to scale. Doing whatever you do in BAU in 10's times more. For example, SCIRT programme did in a month what the city council used to do in a year. It is 12 times, to be able to keep up. It is more about the ***capability to scale and manage the risks after a disaster***. When we compare between public and private organisations, private organisations normally are far in understanding the risks, in terms of disaster situations, and they get their heads far more quickly than public organisations. From the experience, the private sector identified the risks and the challenged almost immediately where the public sector distracted with other stuff like public and civil defence and all the other things that rose up where the private sector, all the current work immediately evaporates. Private sectors had better opportunity to recognise the risks and revaluate and identify the opportunity than public organisations that is why the alliance was important.

- **Insurance involvement**

Participant P11 argued that the complexity ***is vary depend on the location and the volume of the disaster***. For example, the damage in Christchurch was like ***85% covered by insurance*** where was in Haiti earthquake, they had years back, almost zero. So, ***most of the money for recovering came from the insurance companies***; and in fact, Christchurch now in ***a better economy*** ***because of all this insurance money pouring in to people to spend in fixing stuff***. It is actually driving a very healthy economy, post-disaster economy. Compare to Haiti, no money nothing happening, economic disaster.

A lot of it is in how well the people concern and the damage has been insured and the funds are available to put the things right.

- **Complex procedures**

Participant P5 explained that after disaster, there are issues around developing processes and procedures and that was a significant piece that everyone knew it have to happen but probably no one expected the ***complexity around all the procedures*** that should be in place.

Participant P17 stated that after disaster the situation is really complex, and complex projects need more arrangement and in recovery project will need high level of technology; and ***very complicated communications and procedures***.

- **Political involvement**

Participant P18 thought what is different after disaster is the ***wider community exposure*** and that there are ***more political and community risks*** attached to it on a wider area and ***a lot more stakeholders***.

Participant P25 explained that the great challenge in recovery projects are ***the unknown***, ***external influence***, different clients and ***everybody has opinion*** as it is a lot of public money and ***it is essential that money spend wisely***. Lots of constraints, for example, we cannot shut down the whole city to start recovery we have to ***consider the public***, also, think about the ***political reactions***. ***That major risks are totally unknown***. For example, SCIRT initial budget was 3.4 billion and that was just a number because no investigations and that was the risk to manage public expectation and find contractor with a fix price. To manage this risk of ***the expectations on the budget was*** by doing three years of investigations, the budget started from $3.4 Billion then down to $2.9 billion then down to $2.4 billion.

Participant P26 mentioned that often the recovery environment is influenced by ***the politics and the financial benefits***. For example, the five builders in SCIRT programme are a part of this arrangement but the drive to exist here is ***making money and reputation***. It is guaranteed work and money.

- **Media**

Participant P26 stated that all the big companies have ***contingency and communication plans*** like if someone injured, who will talk to the family and ***dealing with the media***. So, you are going to be really careful that the wrong message reaches the media and have day to day ***safety management plan***.

- **Design challenges and design Prioritisation after disaster**

Participant P2 illustrated that recovery organisations need to be aware that what they going to face is not like BAU. For example, there will be ***safety risks*** around working in an earthquake damage bridge and expect that the design is not accurate enough, because of that time factor. Also, ***the design may need to be changed*** and when construction started, there are lots of unforeseen and unknown risks which might be different from design risks, that will required looking to what ifs and ***looking wider***. For example for a retaining wall; the design is done without seeing the extension of the damage and ***what is behind this wall***.

Participant P3 stated we need to ***think differently*** in recovery project. Also, change the way we are doing things to include the earthquake design calculation especially in ***temporary works***; lots of temporary works to support the buildings and the work. For example, with retaining walls we always have temporary work design. We always monitor excavation phases, temporary anchors, temporary shoring. We can't let people work with the risk of something may fall over.

Participant P7 explained how sometimes ***the choice of the design comes back to economics in recovery projects which should be challenged***. For example, in couple of projects, the construction methodology changed to safe more money but because there was no enough expert staff, the projects suffered cost overrun. ***For reason of economics, we chose cheaper options***. That are ***lessons learned***, ***choosing the cheapest option haven't been the right decision***. On the other hand, with the risk of ***time and money constraints***, some jobs could be done without proper ***Quality Control*** or ***Quality Assurance*** because things have to get done. Through the life cycle of recovery, you can see ***the change of design***. For example, in SCIRT behind the emergency work, the initial projects have been designed as ***gold plated*** projects. The very early major projects, ***through the Prioritisation*** of work from the wastewater catchment, to get everyone fresh water, then fix the sewage, then storm water to avoid health disasters, and then end up with the roads. ***These initial projects were gold plated in their design***, everything rebuild brand new. So progressively as the programme went through, we went from project UK style do everything new which burn too much money too quickly in these early projects, and ***year by year the design change*** to fit the available budget.

Participant P7 explained ***the funding challenge*** after disaster and how that affected ***the risk appetite and profile***. For example, under grading the design of the projects due to the funding limitation, by that we actually changed the amount of risk they are happy with, which called the risk appetite. The acceptance of the risk changed because we still have city to build.

- **Time and cost constraints**

Participant P1 mentioned the way to manage risks is the same between traditional projects and recovery projects; we will assist, evaluate, and treat all the risks; however, we ***don't have that luxury of time*** in recovery projects.

Participant P3 stated that programme after disaster; ***you don't have time*** to do traditional risk management procedures. We need to cut procedures.

Participant P6 explained after disaster, ***people have less time***, they are on a hurry, they less tolerant. Generally, they not waste time. Also, there is a potential risk where people will heist. It could come out as wastage of time and delay the decision making. ***When you are in a hurry, you could often take shortcuts***, which will be a ***risk to*** ***cost because your quality gone***. That may cause health and safety influence and affect again the cost. Fundamentally, ***you think you going faster but overall you are slower***, you haven't actually achieved anything because of rework. So that is creating ***atmosphere of pushing things a bit harder*** and it became a real challenge for the organisation to influence on their people to make sure they are considering risks. ***There is always time to do it probably and still meet the challenges.***

Participant P9 mentioned the complexity in recovery projects is financially driven and profit oriented. ***We have very little time*** to do things. ***It is very difficult to anybody to perceive the risk as everyone busy and in hurry***. Then we looking to risk after it happen not before which is not right.

Participant P17 believed that the most important ***issue is time in recovery projects***. Time always the main factor in construction but for recovery project, time is more critical. So, time and cost always relation.

Participant P21 explained that risks are broken down to a number of elements where you set, if you are a client, you will have entirely different risks when you are a contractor. As a client, it is very important to stick with your ***budget constraints*** and deliver what you have to deliver. For example, post the earthquake, SCIRT set up to deal with horizontal infrastructure and fix the damage happen to the water networks. The brief is to restore it to the same conditions it was prior the earthquake. ***Also, what we want to build is greater resilient***. Waste water pipeline are 100 years old, ***using different material with better resilient to earthquake***. Then there is another wider type of risks appeared. In post-disaster recovery, we need to do things ***as fast as possible that is where creating priority list*** is essential.

Participant P26 stated the issues we may face in recovery projects are due to ***time and money constraints***, ***doing the shortcuts***, and run out of money, then not do the job right from the first time. For example, some pipes are bent, and it will be blocked, the cost of maintaining the net will be high. The maintenance cost of infrastructure will double.

- **Aftershocks**

Participant P13 stated that we need to look at risks differently after a disaster. Some people don't look at risk properly until they see the risk on front of them. It takes time to release the outcomes of risk assessment. One of the biggest risks in recovery projects are the aftershocks earthquakes. ***Christchurch had 1000s of secondary shocks***.

Participant P14 thought most of recovery project risks depend on the location of the project and the ground conditions. For example, after earthquake, the water level, and the type of the ground where most of the risks lays***, the longer you wait, the things will have time to settle and less likely to change.*** Because earthquake has ***aftershocks*** and it gets less and less. So, the longer you wait the better. Otherwise, you must work around it, but you will just accept the risk.

Figure E.9 represents the node and the child node of complexity concept using NVivo software.

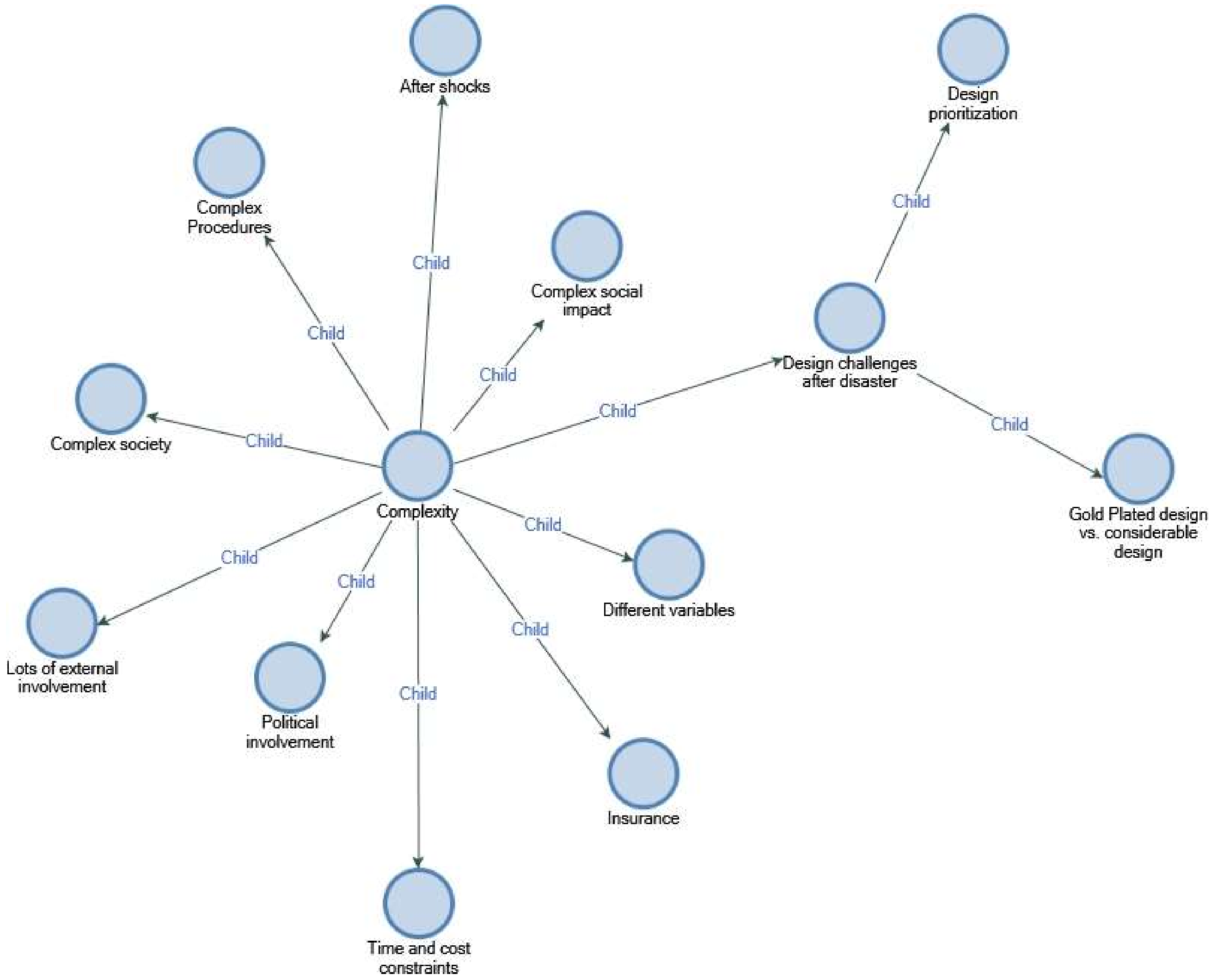


Figure E.9: Node map of complexity after disaster.

➢ *10 Public engagement*

- **Manage risk of public**

Participant P1 stated that first challenge in recovery projects is to ***manage the risk of public*** where the work is open and different stages of construction is happening. People are going to drive through these areas and safety of public is essential. Moreover, the communication is different, such as if you are doing construction activities that have a bit of vibrations, you have to be aware of ***the communications with public*** involved in something like that. There are ***risks to public*** where it could delay the project but these risks need to be avoided.

- **Meet public expectations**

Participant P7 mentioned the public involvement and expectations in recovery projects are huge. For example, people expected to not just rebuild their houses, some of them expected new houses, get new pipes, get new roads and the council felt it is a good idea, everyone thinks it is good idea but the numbers didn't stick up. The insurance values didn't cover that. Therefore, clear communication is vital to avoid any disappointments of meeting ***the expectation of public***. We not see that in a BAU situation. BAU is normally a linear factor, you know what you will get and that will not change or will change by little.

- **Public safety**

Participant P2 explained that with the far end of SCIRT programme, there was lots of more investigations right from the concept design through to construction. However, there were lots of hidden risks, for example, in one project; the decision of going for repair option of the bridge instead of replacing it, even the replacement could look cheaper, is the safety of the people of Christchurch. The risk for the people if tsunami hit the area, they haven't got a way to get out, they will be trapped and drown. So, that was really a big risk that they don't want to be in. So, SCIRT have to put a two-way detour structure and fix the old bridge. So, that was very expensive ***risk mitigation*** for the sake of ***public safety*** and that was taken onto consideration in early stages, the concept design stages. You may choose the more expensive way because of the people.

- **Dealing with irritated public**

Participant P2 one of the major differences between BAU and recovery projects is the ***sensitivity***. The message that you use to deal with the people and the communication is different and the people of Christchurch are the people who working in SCIRT. So, we can't just go and close this road to mitigate this risk without having a real motivation behind that because it may cause ***emotive behaviours*** behind these decisions. If we deal with type of things we should be ***mindful***, ***empathetic***, and ***pathetic***.

Participant P15 stated that ***people and society after disaster are taking risk more seriously*** than before, taking into account what the risks are and to prevent them or minimise them because it is affecting them directly.

Figure E.10 represents the node and the child node of public engagement concept using NVivo software.

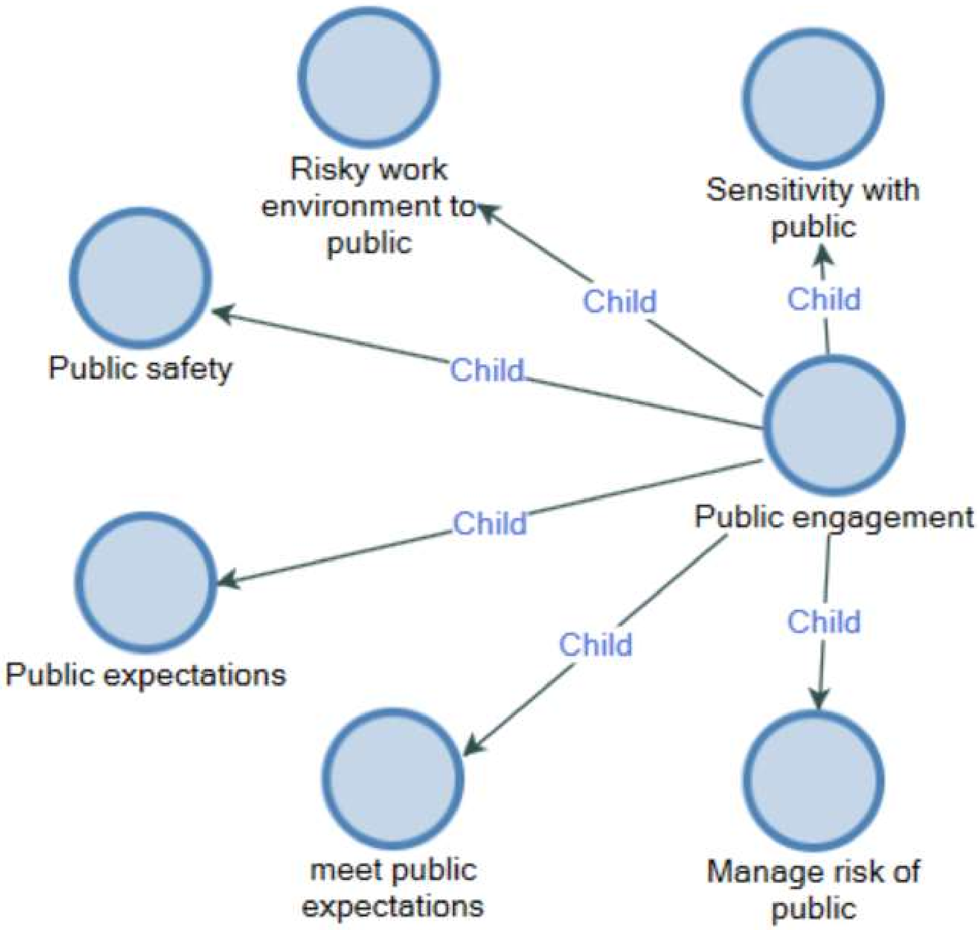


Figure E.10: Node map of public engagement.

➢ *11 Different market after a disaster*

- **Competition in the market**

Participant P2 stated that the volume of work after disaster in huge and ***there is enough work for everybody,*** however it is a bit risky at the end because everyone left town to secure job in more stable environment. For example, the idea in the beginning of SCIRT was to give each team area to work in but after scoring system and some work was not ready yet, the intersection come through. For example, the roaring team has done design long time ago for one project but the pipe works have not been done because of the conflict of interest and the interactions.

Participant P3 illustrated after the earthquake, contractors just did whatever they paid off, ***without tendering*** because of the alliance, companies have secured jobs and because of time factor, it is just get it and get it done. In BAU, there is lot more competition.

Participant P4 explained that in recovery projects, sometimes it is depending on the complexity and everybody want to catch projects that can be done quickly because ***it is important to be the first after disaster in the area***, for some companies, it is about reputation, for some others it is about money.

Participant P14 mentioned that competition could affect the price in the market in BAU but after disaster and with such alliance there is no real competition.

Participant P19 stated the alliance model has its benefits in recovery projects. For example, SCIRT ***was created to reduce the risk of competition and price increase***. Ensuring continuity of work so the people don't have to price high; it has been managed extremely well otherwise that could increase inflammation because of too much work in the market and less resources.

- **Different environment after disaster**

Participant P4 explained that one of the biggest challenges in recovery projects is ***the change in the environment*** and stepping into the unknown where everybody need time to adjust. ***Nobody in a secure ground;*** which lead to lot of mistakes.

- **New opportunities new market**

Participant P1 stated after disaster, there are also ***opportunities*** however; the decisions have to be fast. Such as one company did big donations after the earthquakes, that is why they got the earthquake repairs jobs and then they make much afterwards. Economy after a disaster was shut down a little bit but after a while it started to be pushed by the government and the construction industry from different rebuild works and recovery.

Participant P18 thought that the economy already influenced by the recovery work delivered. For example, in Christchurch, ***a lot of money has been pumped to the market for recovery, and the economy was booming***. However, it is public money, therefore, risks need to be managed well and communicated well, then society will be on board with the programme of work and the economy will do well because of the government and public support.

Figure E.11 represents the node and the child node of different market concept using NVivo software.

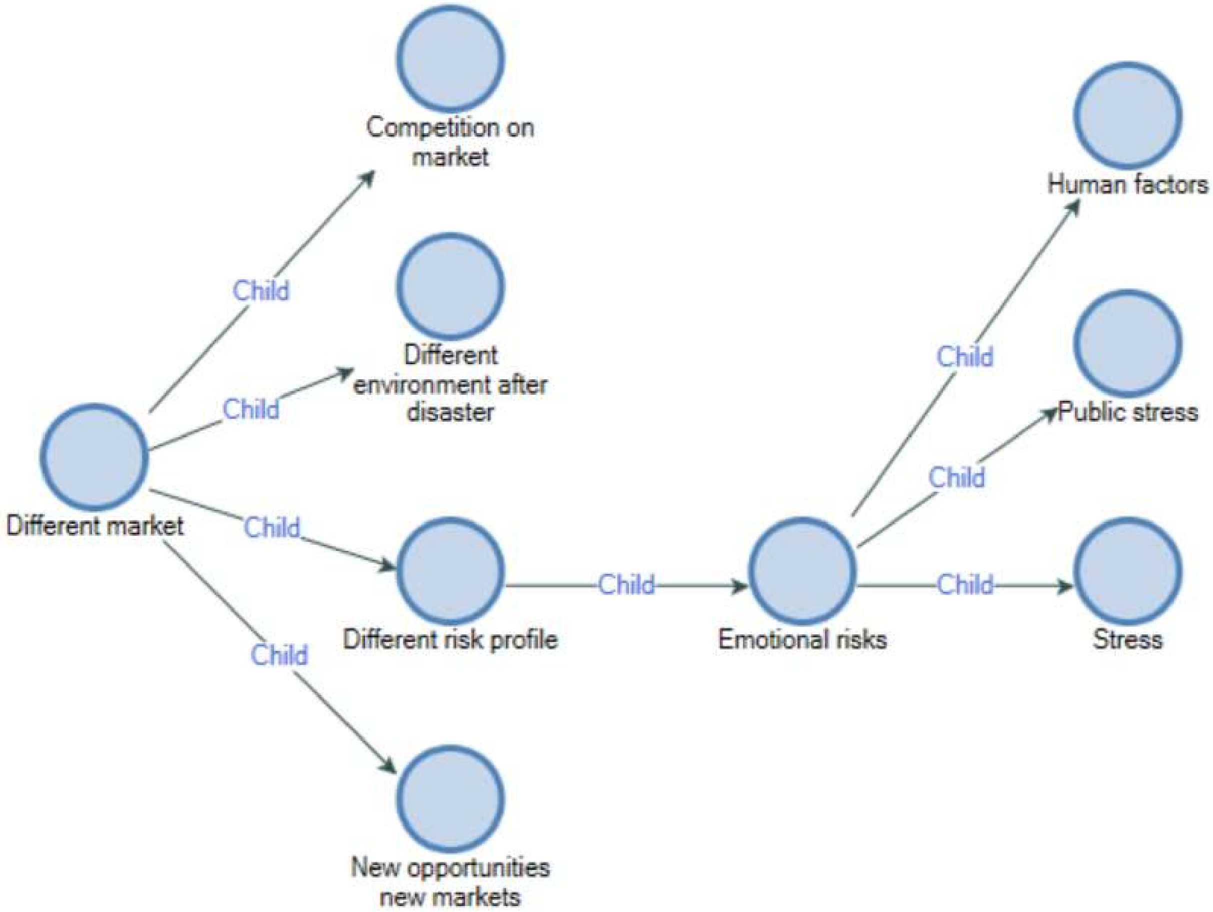


Figure E.11: Node map of different market node.

➢ *12 Different risk profiles*

- **Event related risks**

Participant P10 stated there are different risks in recovery projects based on ***physical changes***; ***the ground is different*** to what it used to be so there is a whole type of risks around that. For example, we may have road was that smooth but now we need to rebuild it or doing patch repairs, now we ***are making decisions*** to patch, according to the size of the repair when you dig, the ***unforeseen conditions*** could be bigger, also, when we try to plan the work where so many other agencies are working in the area such as rebuilding houses or demolishing houses, the working environment is a lot busier. Moreover, the ***people around are a lot touchier***. Contractors in BAU are not generally good about empathy things and ***communications*** never been a high risk as it is in recovery projects. But with rebuild, it is extremely critical to get stuff done. In recovery projects, you need to be very ***proactive*** with what we ***are communicating, with both the team and the public***. ***Some of the risk profiles are quite different*** because of the changes happen to the people and the environment.

Participant P13 stated with recovery model such as SCIRT, we have different projects. We have ***different profile of risks*** after disaster and we also have different risks between projects.

Participant P15 mentioned that estimating wise, after disaster, ***it depends on the situation and the size*** of the disaster, however in general, the ***number of risks increased*** after disaster.

Participant P16 stated ***the actual risks in post-disaster are different***, such as, the actual risks you are dealing with for some projects are bigger than expected with ***more damage*** than you thought, or from the client perspective.

Participant P22 mentioned that ***after a disaster, risks are totally different*** that why we have to share risks with the client in SCIRT model with pain and gain. Like ***ground conditions***, we don't know what was under the ground surface after earthquake. For example, one of the projects cost overruns from $8 million to $20 million because of the poor ground conditions. The ground was inconsistent because of liquefaction and roads were caving in because of the earthquake. No contractor would accept taking this risk.

Participant P26 stated that ***the risks are different*** **in recovery projects and they relate to other threats and that is add to the complexity of risks**. Therefore, it needs critical thinking from people to identify and manage these risks.

- **More health and safety risks**

Participant P17 mentioned that safety is a key risk factor in recovery projects; we have to give more attention to safety for both public and staff.

Participant P3 illustrated from experience, if we keep monitoring incidents, people are going to hide them therefore ***capturing near miss*** is much better. If we focus on an incident, then we will get incident, put if we focus in near misses, stay safe engagement, with this type of thinking we will avoid incident.

Participant P3 stated that most of the risks are after disaster associated, the table of water, after earthquakes, there is no fresh water, lot ***more health risks*** more than BAU.

- **Emotional involvement and Human factors risks**

Participant P1 explained that the ***panic situation*** makes the people behaviours are slightly in irrational way.

Participant P5 stated that risks that associated with disaster that not in BAU includes ***the human factor,*** so people emotionally involved. ***People ability*** to take on demanding tasks and ***individual ability*** to go and work in areas they lost family member, etc., the human factor after disaster is not considered in BAU.

Participant P5 mentioned ***after disaster, community is very different, broken, damage, panic, lack of money, people lost their jobs, etc., lot of emotion going on***.

Participant P3 explained after disaster, people obviously ***stressed*** and small things might upset them up. Usually before disaster, the work will be well planned, and you have time to inform people where after disaster, you may find the contractor in your back yard, some take it easy, some not. No one want to see people get hurt, BAU you get someone got injured, it wasn't really a big deal, where now all the ***stakeholders involved***, ***there is a lot more attention of people getting hurt***.

Participant P14 stated that ***people are irritated after disaster***.

- **Reputational risks**

Participant P1 stated that ***reputation risks*** around that you are doing the right thing have more impact in recovery projects due to public and media involvement.

➢ *13 Risk maturity in recovery projects*

Participant P1 mentioned that measuring ***how well the risk management procedure*** had been used when the risks occurred or not is important in recovery projects.

Participant P3 explained the importance of risk maturity in recovery projects. For example, in SCIRT model, we just needed to lift our game; ***getting better and better*** in identifying the risks going through the hazards identification and really learn from previous finished projects in the same programme.

Participant P14 explained how risk maturity developed in SCIRT programme for more cost controls. For example, estimated jobs 2012, we were actually pricing the risk register and add like 4% to the value. In 2014, things changed, we needed to estimate what is in the risk register, because the ***WSCs*** were put against the project and were already given risk values. But because we not price the risk register, we don't know we have allowed for this risk or not or which risk we allowed for in TOC. That is why SCIRT started to ***estimate each risk*** and try to ***quantify it***. In the early days, we allowed 4% to cover the project risks, then we faced this problem, then we start to quantify risks to ***stop unreasonable or double WSCs***. Some projects were riskier than others, you try to ***listen*** as much as possible. Such as bridges, you don't know how bad the ***ground conditions. Risk management improved over the time***.

- **Risk awareness**

Participant P8 explained that the concurrent type of work in recovery projects needs better risk management procedures therefore, measuring risk maturity in recovery projects is important. For example, in SCIRT, planning, design, construction phases were carrying all in the same time, this is the client, SCIRT and delivery involvement were ***happening in the same time***. In the beginning of the programme, risk management was a bit low in 2012; there was low level of ***risk awareness*** taking into consider it varied between organisations. In 2014, with higher level of construction and higher level of design, there was improvement in level of risk awareness. That is why it is important to ***test the risks against different levels of management***.

Participant P9 mentioned that before disaster people didn't give much attention to risk, there is ***more infuses in risk management in post-disaster.***

- **Risk management performance measure**

Participant P1 illustrated that measuring ***the risk maturity depends on what the risks are***. For example, maybe there is some event occurs and it cost the company some money, the company should check what have been predicted against actual. However, with something like reputation risks, it is hard to measure.

Participant P9 mentioned that measuring the risk management is always hard, it could be a quality check in a monthly basis how risk been performed. How often you discuss the risk could be the way to measure it.

Participant P10 explained a proactive way of measuring risk management in recovery projects based on third party review. For example, the risk pot of money in TOC is a % of the contract that should be taken a side and controlled by somebody else because otherwise the ***realization of risk*** could be hidden by the project manager as he can use that entire budget other project activities. If the risk happened, then this amount of money should back to the contract to easier mitigate or resolve risk from eventuating. There should be ***internal audit*** by the company to control the risk pot. The biggest question is had you spend more money in resolving a risk that is happened vs what the cost of mitigation of the risk would be. So, your risk register will show you how to mitigate the risk and the likelihood and the consequences and if the risks happened, how well you put your risk register together. How well values of the risks, $100k and you have mitigation will cost you $20k then the risk has been well managed. You can say I need to spend the $20k now instead of hitting the risk of 100k. So item by item you should be measuring back and forward mitigation vs consequences.

Participant P12 explained the measure of risk performance inside recovery project should be based on how well the risks registers have been documented, maintained and updated based on the risk profile changes. ***In other words, the risk profile moves, and regularly maintained and updated***.

Participant P13 suggested ***external review*** is essential in recovery projects, however it depends on how project manager treat the project and risks. Two different projects with different personal could have different performance even they are under one umbrella.

Participant P14 explained it depends on how many risks you going to face, if you save money. If risk doesn't happen, then you can ***accelerate the work***. If you got one risk, it may change the whole project. It depends on ***how risky and complicated your project***. You can base measuring risk performance on money or productivity. It can be quite hard to judge but it is always about TOC vs what has been spent.

Participant P17 mentioned that ***risk register has to be alive and dynamic document***. Also, ***documentation and document controls*** are very important which should be controlled by ***auditing.***

Participant P19 augured that risk management is very difficult thing to measure. And in recovery projects, it has to be done with simple ways and simple data that available because of time and money constraints. For example, within SCIRT, one risk was schedule slip and a whole of effort gone to collecting baselines and actual schedule and cash flows forecast. For risk management measure we might use a very detailed and difficult system but actually we back to the ***project management*** information and overall performance to measure risk management because of time factor.

Participant P20 stated that we haven't tried to measure risk management in post-disaster, I think the overall actual cost used in risks, some is commercial, some are time risks, and it is very hard to do.

Participant P21 stated there has been a lot of talking about measuring risk maturity and performance inside SCIRT. Effectively we try to value these risks at the time and put various probability and ***any risks with over than 40%, we try to allow money for these***. The whole risk registers and financial values, some delivery team will use the risk pocket because the risk eventuated. If there was a risk identified and has been mitigated, then we are able to use this money to another part of the project or another project. We don't get any measure; the delivery teams are the only people who know they spend money on this risk or not. For example, you do sheet piles to avoid the collapse. All what you know you done this because of the risk but you don't know if it is ***the right decision*** or not."

Participant P23 stated that it is difficult to have numerical measure risk maturity in recovery projects, however, you need to convert it to dollars for make it easy because it is something everyone understand. For each project, you got a risk register, and a ***risk cost*** for each project and amount behind this cost. The amount of money you paid need to be justify if it is for mitigating the risk or for dealing with the risk after it happen. It would to go back to various scenarios, that is why it difficult.

Participant P24 stated it is difficult to measure risk maturity in recovery projects; however, you could relate it to financial repairing. For example, do you have some ***consistence cash flows forecasting***? You get your S-cure, some steps in the S-curve indicate that something sudden happen in the project. Because everything happening in the project is reflected in their cash flows in both programme and risk level. That could be indicator of your risk management.

- **Measure stick**

Participant P2 explained how the percentage of risk cost could be used to give indication of how the risks are managed in recovery project and rough idea where the things at. For example, for low complex project such as pipe lining project, we expected 2 to 3 % of the project cost would be the risk budget, where something like a drilling project especially after earthquakes the risk budget could exceed 15 % of the project budget. So, if it is really low like 2 or 3 % then the first question is, have you looked to all the risks in enough details? So, the percentage of risk allowance could be used as initial ***measuring stick*** of proper risk identification.

- **No risk management KPIs**

Participant P5 stated that there are lots of discussion about measuring risk management performance and maturity. However, ***we haven't reached to a numerical way*** of measuring risk management performance yet.

Participant P18 mentioned that SCIRT ***haven't got KPI*** for risk management. However, the good risk management is reflecting into financial and health and safety performance. The overall performance of the project is reflecting the risk management performance.

- **No luxury of planning**

Participant P4 stated that there is no difference of measuring risk maturity in normal or post-disaster because risk management is based on the level of disturbance. Only different is that you ***need better understanding of the surrounding*** in a short time. ***You don't have luxury of planning***.

- **Project management measures**

Participant P11 mentioned even risk management is one aspect of ***project management*** but it is essentially part, proper project management cannot be done without it. So, in that sense, if everything working according to plan, just plan will be followed, you will not need to manage it. Project management is about identifying and dealing with where is your plan is not working, and if all the risks have been investigated. How to prevent risk of manifest itself? How to change the plan and mitigate the risk? So, the project management is essentially ***risk management. Therefore, the measure of risk management could be the normal project management measures***, time, cost, budget, same measure where is the project could be describe as successful.

Figure E.13 represents the node and the child node of RMM concept using NVivo software.

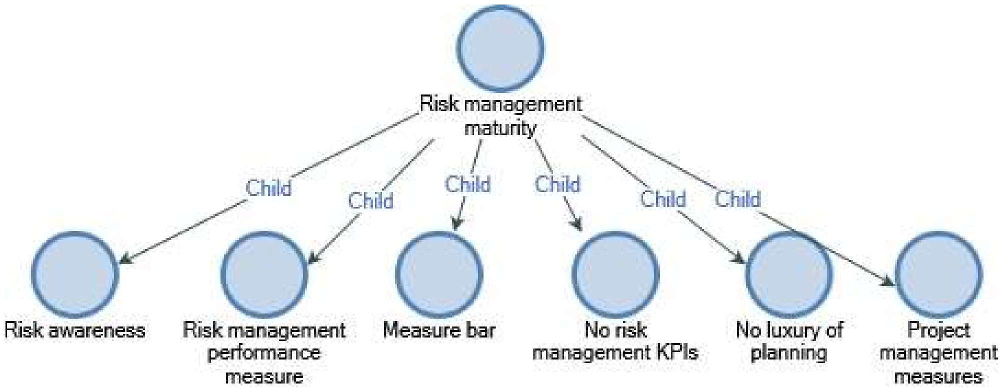


Figure E.13: Node map of RMM.

➢ *14 Quality Control (QC) and Quality Assurance (QA) in recovery projects*

- **Inexperienced staff and lack of resources**

Participant P1 stated that after disaster, it is difficult to get ***professional staff*** as everybody is running out of the city leaving everything behind. ***We don't have the staff***.

Participant P6 mentioned that quality is one of the main concerns in recovery projects which put pressure into post-disaster risk management. For example, the client wants the ***quality right***. He wants to see what he can see is ok and what he cannot see is ok. Therefore, to secure future work, the first measure would be your quality in the previous projects therefore, risk mitigation around quality is important. In recovery a project, due to time and money constraints, normally quality is self-performance module. ***The asset owner*** is taking a risk that contractor has done the job right and ***CCTV*** may bring it up. Also, the quality assurance is around insuring that ***the resources are correctly skilled***. Do the role and competent to do it. It is about the ***quality of the material*** they use. There are so many factors taking into consider avoiding quality risks in recovery projects.

- **Time and financial constraints**

Participants P3 explained in a post-disaster, the attitude always about get it then get it done. ***Quality is not that good as in BAU when you have enough time to do it good***.

Participant P4 stated that nobody wants to be chased by client then it is one of the biggest risks that company not fulfilled all the ***quality requirements***. Client expects to get quality project from the contractor even in post-disaster in short time period which is so hard to be achieved. The best solution is to dedicate enough people to control quality all over the projects. ***Cutting the cost*** by not having ***quality assurance team on site*** and scarifying the production, we are risking poor quality for time and money.

- **Quality assurance and document controls**

Participant P5 explained quality assurance always has been a critical factor however after a disaster; it has been noticing that we have to go in and repair it which makes ***a lack of administrating evident of quality assurance in projects***, therefore, document controls are essential.

Participant P7 explained doing ***conservative design*** in all perspectives, testing every single activity, and having the ***quality document*** for every piece is crucial. The product that you are installing should be with low risk high quality expectation and to last forever.

Participant P17 mentioned ***the time is critical*** in post-disaster therefore; we need to ***do the job right from the first time to avoid any delays***. That is why quality assurance is so important. ***Quality affects the risk management.*** Because most of the projects are ***fast track projects***, we have to balance, quality with delivery on time. We always give time more attention than quality which is not right.

- **Training and upskilling**

Participant P10 stated it is extremely important to ***check quality onsite*** in recovery projects. ***CCTV*** is a great example in SCIRT; some project was not working probably to the level it should be and they have been asked to redo most of the work. Also, some pipeline projects, it ended up with ***rework*** due to ***not enough experience and not enough training***. Quality and risk management are related. It is to make sure we ***follow the specifications*** and we have ***process in place*** to meet quality requirements. ***You need someone from the outside to look to your processes*** to make sure that thing wouldn't slip from the crown in your process because too often you can get really involved in the process and not actually have somebody ***looking at the bigger picture outside***, ***review it from outside***. With proper ***quality assurance*** running through from the beginning of the programme, we can ***learn the lesson*** ***early*** instead of carrying it through. And again, an outside organisation looking to your quality assurance and how you are performing internally is important. It will endorse international practices and help you get through the programme delivery and promote ***best practices."***

- **Smatter procedures**

Participant P11 talked about the risks that not done probably, of having ***the end result not fit*** the purpose or worst in recovery projects. ***It is a hazard itself***. This is obviosity very important ***Quality assurance*** could be technical, but you will need to expand the definition to deal with everything you do. Follow the right ***procedure*** around all the surrounding including environmental or safety.

Participant P12 explained ***quality assurance*** added to the risk. For example, ***we had issues where city council has been excluded from QA*** but when we were off into our own, council felt descanted about it and ***the self-driven model***. However, we come back to do what the council want us to do. The risk profile increases due to the low involvement of the client.

Participant P14 explained that the quality has improved after disaster from what it was before the disaster. For example, companies collected to much information of the asset that not even been there before the disaster. Companies are ***improving the resilience*** of the pipes for example.

Participant P21 mentioned that generally a lot of construction projects have quit ***extensive quality assurance requirement***, ***processes***, check list and lots of parts involved. The risk where you get programme like that with lots of jobs, they are ***relatively low value and short duration*** and one after the other. There is real ***potential that you may scarify some of the QA***. We are in a post-disaster situation, and we ignore some of it. Companies not do lots of QA activities to have enough time to deliver project sooner where in reality this work have been rejected and ***redone***.

In BAU, the government has its ***external agencies***, they come around and client never trusts the contract and they come to inspect all the activities and insure it is under the client specification. The industry went through a quite transition to make ***quality assurance internal procedure*** in house. If you are going to do it in house, the owner of the asset the one who will suffer. There were quite change in procedure to ***avoid delays*** on the job because you will need to book them to come and check if they will come and inspect. So, it is a real pain, and long procedure it ***takes from the job momentum, then we have gone to internal QA process***, it took effort to get the process in place and make teams used to it. Besides, you can do random audits to avoid delays.

In SCIRT programme, without good ***internal assurance team, it is hard to deliver such huge programme on time***. Each delivery team has its own quality manager who control and manage the quality of the project. What we have today is really good; it took us two years to gain momentum. Something is good. When we see projects and programme of works and number of fatality, we are far better. When we are looking at quality of the work we are producing is far better. We still need to do more improvement and effort, but it is very good in total.

- **Different priorities after disaster**

Participant P19 stated there is high risk in quality assurance in recovery projects. People often need to ***cut corners*** because ***no much time***. It is a massive risk in post-disaster because ***your priority the safety of the people*** which come higher than meeting all the tests and standards, and most of us ignore the quality because of that.

- **Self-performance quality approach**

Participant P24 stated that in SCIRT, we have ***self-performance*** in the quality space, where in BAU; you will have external consultancy, come, and check everything. It comes back to ***resource issue***, with the ***volume of work*** we have, and with the model we are operating under, you will need an army of checkers. The tension around the self-performance quality, we have five of the biggest contractors in the country and they are ***competent*** ***enough to self-manage their quality*** and credited. It is an efficiency thing, so you can ***self-perform quality faster and delivers work faster***, it is two folders, ***resources*** constraint and ***productivity*** too.

- **More investigations**

Participant P25 explained that if you look at risks around quality assurance, there are ***investigations*** for example, pipelining, you send your camera down, that is so expensive and time consuming, that you knew the pipe was damaged, post-disaster, you make cracks on the pipe and send the cam down, to find the repair, ***when you put QA into that, it is really so expensive***. So of course, why you spend lots of money to send the camera down for what you already know by ***visual inspection*** and see this is broken, the QA in term of did you meet the council specification to get that repaired, it would not be as original one. This is example of you need to change your Quality procedure and again in terms of how you manage QA in post-disaster into the budget. Design specifications changed couple of times in SCIRT to make us fit within the budget.

Figure E.14 represents the node and the child node of QC&QA concept using NVivo software.

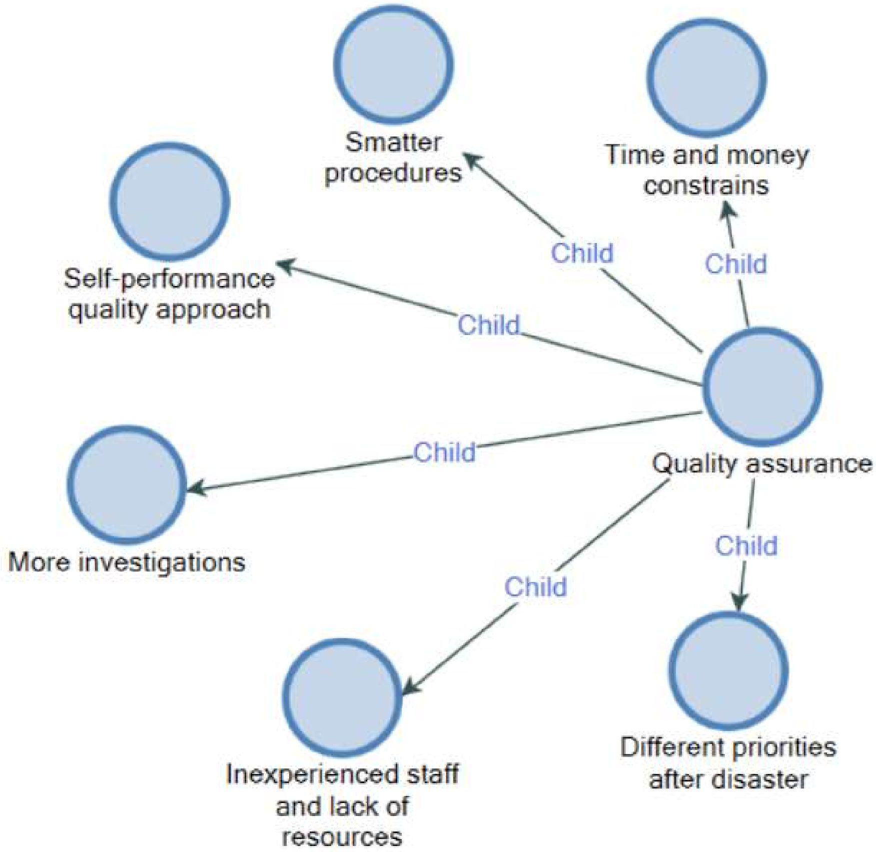


Figure E.14: Node map of QC & QA.

➢ *15 Risk management approach "Centralised vs decentralised approach"*

- **Mixed approach**

Participant P1 mentioned that best risk management approach in recovery projects depends on ***the type of risk***, for general risks on site day to day; it must be managed by project team on that site. If we are talking about major risks around ***future work*** and ***strategic decision***, it is probably better to run centralised because people onsite they will not know much about this stuff. So, ***it is a combination of both***.

Participant P2 explained that ***mixed approach is better for recovery projects***. Decentralised to let project manager involved and take responsibility of the risks in his project and be ready for the outcome. If it is centralised with just one-person control risks, the project manager will try to avoid the responsibility. However, if you have ***a centralised person*** or team you will get ***more consistently*** on the way the risks have been managed.

Participant P5 thought that ***mix approach*** ***would be more effective*** in recovery projects.

Participant P18 believed it would be valuable if small team focused in ***strategic risk management*** and trying to identify risks that coming up to achieve risk management ***best practices*** and ***then risks will be foreseen better by a risk team***. For example, in SCIRT, whatever we were putting a lot of pressure to delivery teams regarding pipe lining projects. Maybe having ***combination of centralised and decentralised***, giving ownership back to the delivery teams, and project team to look at the strategic risks over the programme would be beneficial.

Participant P19 thought ***decentralised*** give the chance to risk management people to see and involve into the risk, they will have better effect because they are near. However, some people are not aware enough of the risks. Obviously, with SCIRT, you can steer, one of the risks is ***cost escalation***. That is why this model has been created, to control the cost in the market. In immediate post-disaster areas, ***risk was*** ***identified by mangers and down to align structure***. It was until we communicate it down that we are going to have TOC, things needed to change, and people focused in ***cost management*** and that risk to the whole organisation. However, the people in the field didn't know about it. They thought it is cost plus.it wasn't until we ***communicate*** ***it down***. In the beginning of the programme, there was some cost overrun. Things need to change, and people need to do cost management and then people realise that they need to put ***proper framework*** in place and to try to beat TOC. Therefore, ***you need to have centralised system to mitigate the risks but also decentralised and you push it to everybody, so they have better risk awareness***.

Participant P20 mentioned that combined approach is more appreciated in recovery projects. In SCIRT model, we had programme risks, which are centralised, and project management risks which are decentralised.

Participant P25 believed mix approach is better, ***the organisation and the board*** can see the overall programme risks and decentralised depend on project by project bases where teams manage risks.

- **Decentralised**

Participant P14 believed that decentralised is important because the way you can see risks ***depend on the people onsite***. But people with previous expert can add to the table. It definitely depends on the previous experience.

Participant P3 thought ***it should be always a group input*** not just one person because you will miss lots of things.

Participant P4 illustrated in big organisations, the executive managers or managers on field, they manage small risks all the time in BAU. In post-disaster, it is quite different because it required ***quick decision making*** and therefore, you cannot have ***centralised system which will required more time***. So, after disaster it is all about recovering as fast as possible is not about waiting some hired manager to have a decision which probably 50:50 wrong or right. You need to be able deliver jobs with ***lots of unforeseen*** and manage your own risks.

Participant P7 said it depends on the kind of ***risk profile*** we are accepting, it has been centralised, this is not design and build, we just construct. It had been centralised by SCIRT and stakeholders, but that decision making are centralised. In SCIRT model no one ever loss. All delivery teams are making margins. When these projects over budget, we still making our budget so the simplistic to get things right, to be more risk reverse you are going to make sure you get it right from first time. Perhaps ***it should be decentralised*** to give individual delivery teams the chance to critic the design for example. For example, one of the projects, the preferred option in the design was a ***political decision*** to maintain access to south shore if a tsunami happened. So, they make statement to secure exist and that decision was a political decision and ***it change the design*** from new bridge to repair the existing bridge. The engineering decision was building new bridge as the repairing the bridge cost as twice as a new bridge. Such situation explained how it was a centralised decision, if you did it decentralised, the decision would be new bridge.

Participant P11 thought it is same as any activity, ***more heads are better than one***. However, risk and the mitigation of the risk ***should be owned by the people who are directly affected***. You can have your experts in subject, environmental expert or safety expert; but the people responsible to mitigate the risk are the people who are doing the work. ***They have to own the risk*** and involve on it. It is also depending on the type of the risks. Best example is safety on sites. In the morning, site engineer or supervisor who is the boss on the site, he could just say these are the risks and this is how we will deal with it. We found it is more successful if you stand with the crews talked about what work they going to do and then invite them to have ***2-way conversation*** of what are the risks associated with this and how we are going to deal with it. This is ***decentralised example*** and that is the most effective thing. Everyone who involved to certain activities; they have the risks and be aware to not just contribute to risk also coming up with the ***initial assessment*** of what that meant to be.

Participant P12 mentioned that ***risk should be managed by the team***, when people involve they own it, looking after it. Risk managers are mainly managing the process not the risks therefore, it should be owned by the team or the group of people. It is important to have a systematic procedure.

Participant P17 stated that one-man show is from the past. In post-disaster, ***it is more about team work***. You need each idea and all the ***skills***. We don't have enough information about the risks, so we need all the effort and the skills from all the time to identify the risks and how to mitigate that is why decentralised better than centralised.

Participant P26 though as long as the project team is good enough to manage risk, then decentralised the better option. Centralised would add more layer of management but it will still not stop the event from happening. If you need risk management effectiveness, having separate risk management department is not enough. I think the people that they are doing it; they should manage their own risks.

- **Centralised**

Participant P9 recommended ***centralised*** for recovery projects, it has to be senior person ***who knows*** about construction and the projects to drive the formal risk management structure.

Figure E.15 represents the node and the child node of risk management approach using NVivo software.

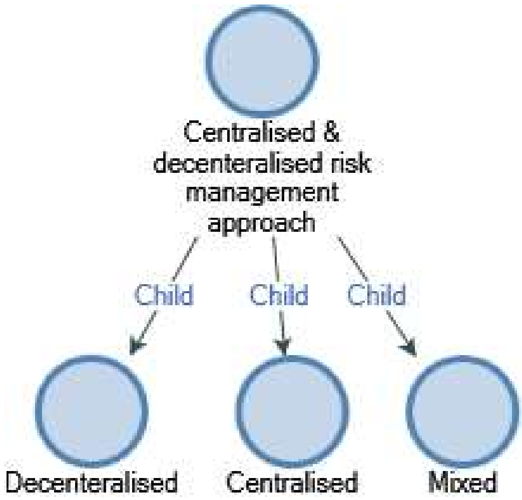


Figure E.15: Node map of centralised vs. decentralised approach.

➢ *16 Prioritisation strategies in recovery projects*

Participant P1 stated that ***the Prioritisation for the risk*** point of view is an important part in post-disaster risk management.

Participant P5 mentioned that one of the important pieces in recovery projects is ***the Prioritisation and the management*** of that Prioritisation in the programme which means that your risk register will be different from the beginning of the programme. For example, the risks direct after a disaster and ***emergency works*** is different compare to 3 or 4 years down the track.

Participant P7 stated recovery programme is based on Prioritisation, for example, in SCIRT, early on; the ***high priority*** gets clean drinking water to the people of Christchurch, not to deliver a product that stay 100 of years.

Participant P10 illustrated that risks direct after disaster is different from risks after 3 or 4 months after disaster. For example, you might go and do repairs it cost you more 20% than you normally could do later on, but you will be forgiven, because you want to get it done fast due to emergency. The planning that should be done is less in emergency works; you expect additional cost for that. You will need more time to refine this work, so you will not waste so much money. Because you are mitigating the risks and you get more accurate designs. Some of the work done in emergency we done some repairs and it cost us lots, what happen with that now; we put it back into system to fix it again. Should we wait until we design it properly and let these people suffer without sewage services? Actually, this repair may be taken off, or maybe not used again. ***You just do it to avoid critical risks such as mass diseases*** in Christchurch and as the programme progress; there is different profile, so a risk register should be always alive document.

Participant P19 thought we need to concentrate in the most important risks. The success come though identifying risk, ***prioritise risk***, and then acting in the most important risks first. For example, we identified very early on that ***the safety risks were the major*** and important in SCIRT programme, so we concentrated in that. In the ***second year was more about the systems***, we concentrated in that. How we going to control the projects and divide the projects, how we going to use one system? We really only limited amount of systems available for us, we do ***priority list*** and see the highest risks to the organisation and what you need to do to mitigate that.

Participant P26 mentioned that the earthquake is representing an opportunity of having new works. For example, the temporary works required to ***protect*** and support the construction, the building and the staff. You have prepared for ***aftershocks***. As we have limited time and to avoid delays, we need to create prioritise the risk register. Put the biggest one on the top and do your best to mitigate them. ***Prioritisation is the challenge*** to get on top of the risks and the programme and avoid any delays.

Figure E.16 represents the node and the child node of prioritisation concept using NVivo software.

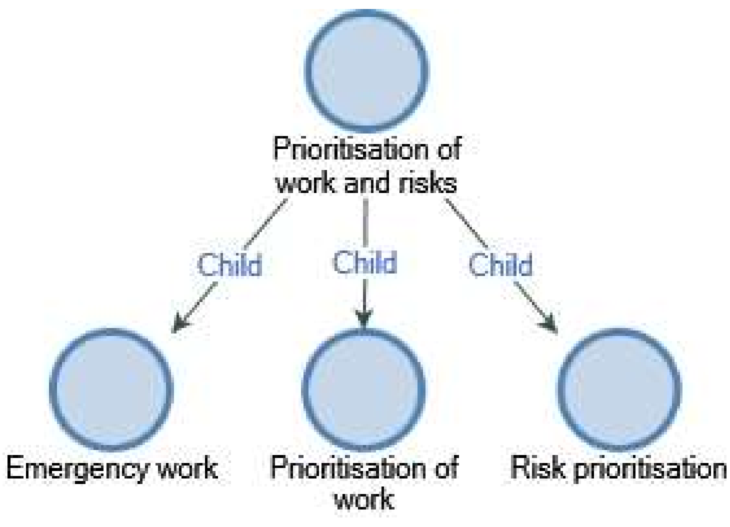


Figure E.16: Node map of prioritisation.

➢ *17 Undefined scope of work and uncertainty levels in recovery projects*

- **Limited investigations**

Participant P2 thought ***knowing what you do not know*** is the biggest challenge in recovery projects. It is more about ***not knowing what the degree of damage*** really is due to limited investigations in the beginning of the programme because of time and money restrictions.

Participant P16 said after disaster, ***the scope of work is unknown***; you don't know the damage due to limited investigations.

Participant P17 stated that ***the main challenge is unknown risk***. In BAU, you normally know more about the risks, but after post-disaster, you cannot calculate the risk level and you can expect unknown risks because you ***don't have enough information***.

- **Undefined scope of work**

Participant P9 stated that the biggest issues ***the understanding of the work*** and the project. ***The scope of work*** is not completely defined yet.

Participant P11 thought that the greatest challenge is ***the level of uncertainty***. Typical project in a stable environment, you can certainty identify the risks to certain extend and quantify it ***based on previous experience*** for some of the projects. In disaster environment, they usually face ***unique situations*** with lots of uncertainty. You don't have baselines or certain information available. You need to get out and get it done. In that case for example, we took 3 to 4 years to just complete the ***assessment of the network and fully identify the repairs*** we had to do. The risks around ***unknown scope***, also, the uncertainty around have the disaster finished or we will get more earthquakes "***aftershocks***". You have the uncertainty around it is not a planned event, so the ***uncertainty about funding*** of what we do; also, risks around the ***social***, ***the demand of population and demand of politicians***. Uncertainties to have that unfold because after each disaster there is a sense of revolution process. ***People go through phases***, they follow a bit of a ***pattern*** of needs and demand that changes with time.

- **Future works**

Participant P1 mentioned that the struggle after a disaster is the organisations and construction companies ***do not have*** ***certainty of the current work*** or the future work as if they will actually continue or not. Lots of thoughts like do we have to disappeared and do something else, how the client is going to react to the earthquake, what are the client priorities. The continuity of work is a hot point especially at the end of the programme.

- **Specific risks**

Participant P3 stated that risks after disaster involve ***more underground conditions***.

Participant P14 mentioned that ***anything under the ground*** and you cannot see it, it is higher risks after disaster.

- **Uniqueness**

Participant P5 explained the main different between BAU and recovery projects are the ***quantum*** of everything and the risk profile. For example, in BAU you ***have time to check all risks*** and you have ***a clearer scope,*** so you understand to manage risk that associate with that scope. When you deal with disaster recovery, there is often ***no clear scope*** until most of the work is completed. Especially you are working with alliance where your client has multiple parties and scope being the biggest challenge. So how you do address risk around scope you are not aware of. ***Front planning*** and trying to facilitate ***more resources*** and address the issues before it happens is critical because of the ***unique situation*** you are in.

Participant P24 thought recovery projects are different and it is ***total unknown*** in a disaster situation. We ***are facing risks we never faced or seen before***, from the ***ground conditions***, ***liquefaction***, ***settlement*** in some area. For example, ongoing issues with pipe, you put pipe on the ground and you face aftershock earthquakes and this pipe moved or the profile change. These kinds of risks you will not face in BAU. It is impossible to give this risk to somebody over another, so it was the best option to ***share the risks.***

Figure E.17 represents the node and the child node of uncertainty concept using NVivo software.

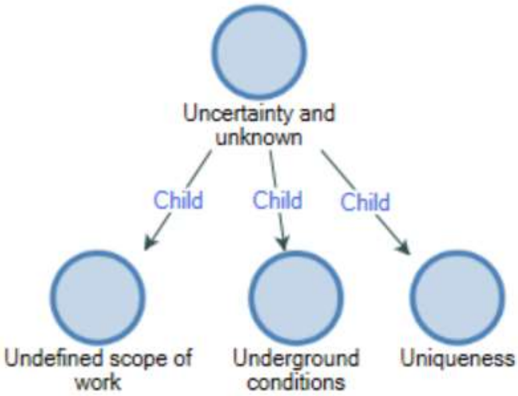


Figure E.17: Node map of uncertainty and unknown.

➢ *18 Interaction and conflict of interest in recovery projects*

- **Intersection of work load between companies**

Participant P5 mentioned that there is ***the risk of intersection of work load between companies***. Also, direct after the earthquake there was a ***huge movement which affects the resources availability and continuous resources drain.***

- **Intersection between project lifecycle phases**

Participant P8 explained that the biggest risks when we do ***concurrent activity***, like developing design and constructing at the same time, ***there is no opportunity to consider risk probably*** and the danger of not having the risks fully identified. For example, even SCIRT was revolution from start to end, however, early stages no one was account for risk properly as there was no time for it. Later on, ***the risk maturity*** increased, and ***accountability*** of risks became more formalised. In a way, there was ongoing concern that we were constructing the projects with no fully understand of risks and that what happen for early projects, however, avoiding ***the work to be slow is coming through the process***.

- **Intersection between different sectors**

Participant P23 illustrated that the success in recovery projects comes by public and private ***cooperation***. ***Public can manage response from a very high level but relay into private organisation to go into it***. Creating umbrella organisation to drive recovery programme and endorse the procedure with enough ***flexibility*** to allow the private companies to use ***best practices*** to manage their own risks was a successful story of the cooperation between public and private sector.

- **Intersection between resources**

Participant P6 described that in recovery projects there is a lot happening, ***there are lots of people involve and all going in different directions***. Not all necessary working in the same project. So, it a lot ***more cooperation required***. Risk can be about the effects of one aspect of operation which affect another aspect of operation in term of creating a delay or could even be ***friction between working sites***. For example, ***traffic management*** is passing through where you want to work which forced company to be cooperative. Therefore, risk management in recovery projects is more about scheduling your time to avoid wasting money and wasting resources and stopping friction. There is a lot of work going on therefore, we ***need processes in place*** so, everybody knows what they have to do and how they have to do it. If in an event of a disaster, you try to figure out what you have to do then you are wasting time and ***all going in different directions, so you need process in place to go step by step*** so you don’t have to think about it to reduce stress and avoid wasting time because time is critical in recovery projects.

- **The conflict of interest**

Participant P20 stated that ***the conflict of interest between delivery teams in one area*** is a challenge in recovery project but it is important to create competition model. If recovery organisations have been assigned separate areas, it has the potential to restrict the competition. For example, the key element of SCIRT is that recovery organisations are getting work based on the success of doing well which influence positively the performance, ***the attitude performance is governing by the knowledge of if they did well, and they will get more work***. So, losing a project is very important. Teams start working with equal shares of projects and it ended up that the top team had 24% and the low team had 16% based on the performance.

Figure E.18 represents the node and the child node of Interaction and conflict of interest concept using NVivo software.

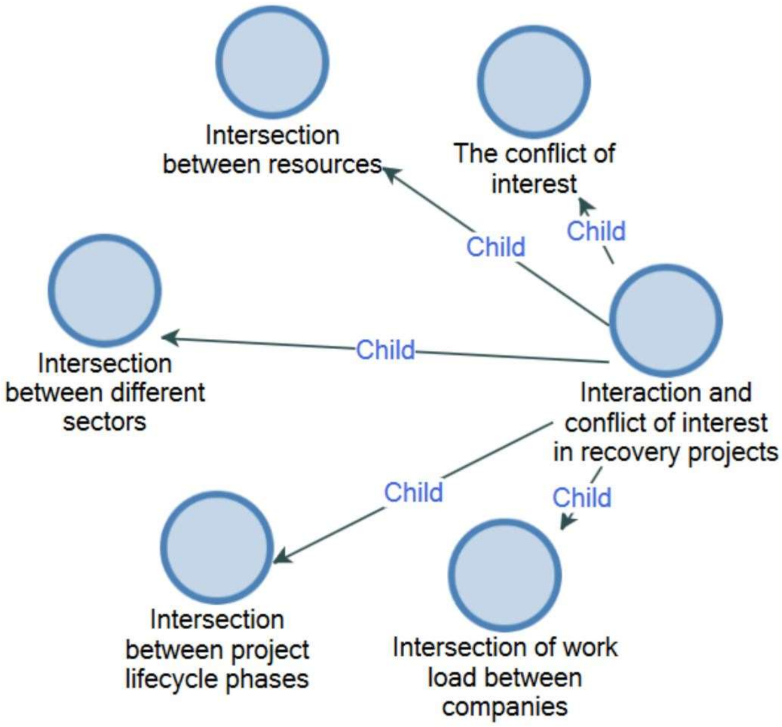


Figure E.18: Node map of Interaction and conflict of interest.

➢ *19 Processes, legal changes and consents*

- **Consents**

Participant P2 illustrated that one of the challenges in recovery projects is dealing with council ***consent and legal requirements.*** For example, if you go in the normal way you will be forever chasing your tails to get your project of the ground so how to manage this and to integrate your demands and mitigate risk of ***slowing down the delivery*** and the speed in which it is granted to keep things going. It is depending on what type of consent you need to get for your work. For example, when we are working in the main roads normally we will not allow driving diggers in the ‘A’ street because it discharges seal, but the council knew we going to have to get down with diggers in there so we have to had risk management in place, such as ***environmental risk management*** plans in place for these actions then the council have to give a bit of a space to let it happen. The risks of use bigger diggers with long reach which is it is heavier which may damage the existing road and then how to get traffic around it.

Participant P3 mentioned that lot of ***consents*** you need to get in recovery projects, like heritage consent, biological consents, or resources consent, these types of consents need to be secure as fast as possible to avoid any delays.

- **Processes**

Participant P10 illustrated after disaster, the work volume expanded massively so government created the organisation and gave it ***certain level of independence***. So, we still doing the same checks that we normally do but we are ***not going through a normal process*** with council. The same people are taking the same reasonability, but they are in the same building which cut off the waiting procedure. Process Statements (PS) 1, 2, 3, 4 are all happened indoor. It is important to create fast track procedure by ***leaning the procedure to make everything speed up, it is a bit of time saving.***

- **Training and technical support**

Participant P6 illustrated when we have a major event, ***a lot of things happening at the same time*** by a lot of people and there is a high potential ***the specifications would be changed or updated to fit the new circumstances***. Also, the asset owner and the recovery organisations would try different ways of risk mitigation. The risk there would be is to ***produce an item that you are not familiar with***. Also, the updated and changes should not be happening half way through a project. This type of risks is hard to allow for but processes for risk mitigation should be in place. Also, it is important to have ***training*** in place for the new changes or specifications. For example, if we are using new pipe system with new product to avoid the risk of producing item that you are not familiar with.

Do we have time for training in recovery projects? The answer is yes and no. if you introduce new products, new material, for fresh time use, then it has to be time to get up to speed. Or you could bring people with enough experience. But generally, around a disaster, you are bringing people, and because of the volume of work here, lot of site engineers have been worked with no enough experience. So, a manager somewhere is taking some risk of giving a greater volume of work to ***young engineers***.

There is no financial penalty around doing it. So, change in material and specifications are risk. It will come up from time to time. This is highlighted the need for ***expert staff*** or additional ***training*** when required, also, the ***technical support***, the ***testing*** and ***recording process.***

- **Legal changes**

Participant P9 legal risks are important, sometimes staff on site are not really ***aware of the legal risks*** associated with the recovery works therefore, it should be included in the risk management plan and how to avoid it.

Participant P13 stated that there has been quit few changes in the standards and regulation after disaster such as ***safety regulations***, to include the impact of earthquake, ***changes have been made accordingly.***

- **Change in specifications**

Participant P20 explained that the changes are common in recovery projects, even the internal guidelines have changed. For example, the guideline that defined what we did in SCIRT, the Infrastructure and Rebuild Technical Guidelines. How and what we were rebuild. It was defining scope based on damage. For example, if you have water main with 3 breaks, you repair the line. If you have 10, then you replace the line. That was been used for the first 2 years. Then came along another version called ***level of service*** which means we assist the damage and decided if it will affect the level of services in the future. So, it is different way based on the ***performance of the line***. In the case of a road, the future of that road, based on how heavily the road going to be used. Then later on, there was updated version in which it was concern more of how much remaining of the asset age and we have to ***assist*** ***how much life remaining in the pipeline***. In some cases, we just ignore the breaks because it has just 5 more years of life. ***This reduced the rebuild scope*** from $3 billion to $2.5 to the $2.1 billion.

Participant P24 mentioned that the challenge after disaster is to ***understand the new changes*** and ***specifications*** over SCIRT life cycle. We tried to manage when specifications changes, we need to communicate that and clarity and there was ***a risk of doing things not under the new specifications***. It depends on where you are looking to it, ***it is important to change specifications and regulations to meet the new requirements*** and disaster situation. For example, we have learned that the pipes could move due to earthquake of aftershocks, and then the pipe specifications have changed to meet the new requirement. These types of changes need to be communicated well. However, ***there was a risk to miss some of specifications because it changes quiet frequency***.

- **Client demand**

Participant P1 explained that there is a risk depending on what the ***client needs***, the volume of work and how you are going to pay for it, therefore, your risk profile could be changed due to client involvement. For example, the client could push some risks into us ***and it is important to have clarity around that***.

Participant P2 explained that there is increasing in ***customer demand*** in a post-disaster because everyone wants everything to be fixed fast with a good standard and try to mitigate risk of unsatisfied customer.

Participant P17 mentioned that in recovery projects, the public are our main stakeholder and we are there to meet customer needs, so risk management have to give more priority to customer demand and mitigate any risk.

Participant P19 explained trying to keep up with the client requirement is difficult in post-disaster. Risk management within post-disaster is ***dynamic*** going from ***emergency response*** to ***initial recovery*** to ***short term recovery*** to ***long terms*** to ***restoration*** and quickly go back to ***BAU***. In each phase there is different customer needs.

Participant P21 explained how the client requirements have been captured in SCIRT programme. SCIRT has the role from the asset owners to ensure the infrastructure is restored. SCIRT undertook ***asset assessment*** to check what is broken. Doing ***CCTV*** and flush out the lines, then you assist the damage and then all design done by different consultants under one roof. Then it broken down to projects, we do concept design and looking to the options and stand one solution and discuss with the asset owner. Then do all the detailed design undertaken along with the ECI with ***contractor***. Everybody in this building, they all basically engage ***the designer office*** to provide the expertise to do the design but under one roof. We split them into four teams, however they ***represent 16 design organisation and 180 designers***. Design guide line has been established by the client and they have to come out with design that complies with the ***client specifications***. It is complete ***design build solution*** and they called it EST. We then give it to a delivery team to execute these projects.

Figure E.19 represents the node and the child node of processes, legal changes and consents concept using NVivo software.

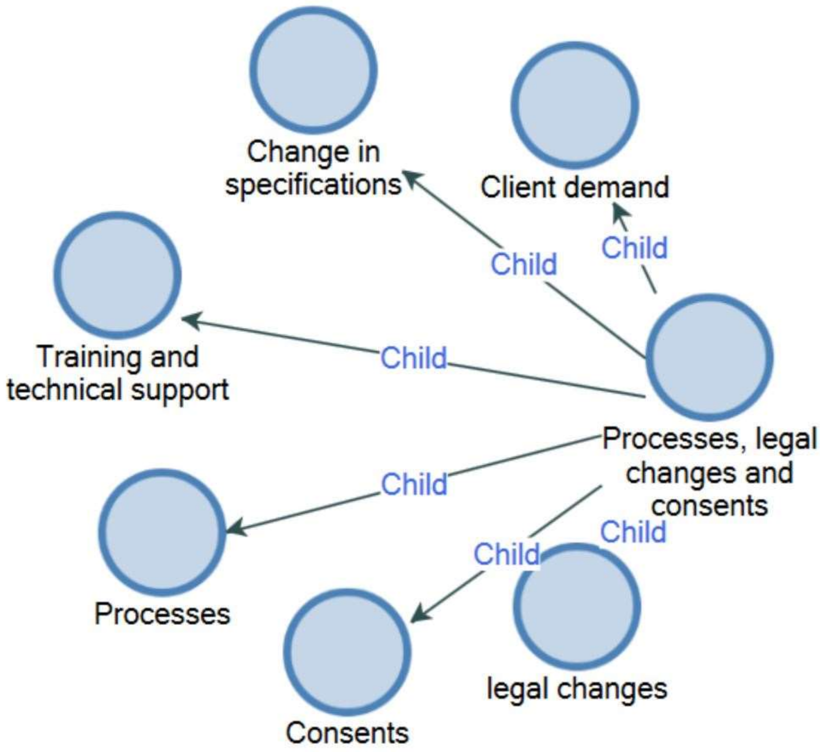


Figure E.19: Node map of processes, legal changes and consents.

➢ *20 Leadership and decision making*

- **Front planning and right leadership**

Participant P25 illustrated that it would be great to have earthquake one to one manual or plan, when massive earthquakes happen, then you open the manual and the recovery plan which is easy to read. For example, let us go through the matrix, we need to create governance team, we need to setup alliance and this is the time frame. Then you get the alliance created in 6 weeks. Also, you need front risk management plan, such as the risk of people leaves the city and lack of resources. The ***governance*** response needs to be quick and they need to push the ***economy*** and ***contractors*** to stay. People took long time to check who should be procured and took longer time, a year to get this procured. Stay for a year doing nothing is just not acceptable after disaster. People are in a ***tension situation***, people want hope. At lease in SCIRT, there was a good story, things were moving, and things were happening. The risk if you don't have that manual when you will have such event with that size, you get gaps and lots of risks. The ***right people*** on the table are important. SCIRT response was ***unique***, with five main contractors with all the top people in the industry including ***the executive leader team***. ***The leadership*** should be strong and one of the things you need to strongly have after disaster.

Participant P26 mentioned that ***leadership*** has its effect upward and downwards on ***planning*** and ***organizing*** the ***objectives*** and the strategies. In other words, who, when, how and what would be done, supporting the ***innovations***, endorse the ***teamwork styles, then systems***. You need to build the ***strategy*** right based on the team then get the big picture right, then go to smart systems to get all details on. It is time to get outcomes, results, cost, quality, safety, and relationships and reputations with all stakeholders. Good leadership is about organizing which is allocating the activities to right peoples with the ***right skills*** doing the best work they can do and enjoying it.

Under implementation you need ***decisions*** from the right people, you have to train them and delegate to them. From risk management view, none of these management tools works here without ***planning***. The best managers are good planners. For example, instead of having 100 risks, five you are really dealing with by doing effective Prioritisation. All risks are covered, and for these five you have a plan and contingency. You have to nail the big ones, and then it will have huge effect on the rest. That is how to cover the risk; you have to find where your main risks are and balance the risks and the opportunities. The greatest project managers do things in a regular basis and do it very well. The good leadership is how to get the job running, get the strategy in teamwork, hitting the programme and then control the budget and the risks.

- **Culture**

Participant P23 mentioned that ***culture*** is critical to ensure risks don't occur, it is basically like ***leadership***, we want everyone to know that risk management in recovery projects is critical and they have put their mind and effort to be aware of risks.

- **Market and political involvement in decision making**

Participant P7 explained the influence of political and market into decision making in recovery projects. SCIRT has been created as hierarchy system that contained delivery teams report to SCIRT who report to the council and they report to even higher stakeholders NZTA, CERA and central government. That changed the risk appetite from the upper of the hierarchy to the bottom. Also, the market had its say and the council with no enough money to fully recover the disaster, so, the ***market forces had to change their decision making*** against their first judgment. The engineers in the council much prefer that ***we continue building gold plated projects, new projects, do it once do it right, best quality project*** as it is the best ***engineering decision*** however, this approach is expensive, therefore the choice was to be repairs, not replacement. It is a combination of ***political decision and market decision after disaster.***

Figure E.20 represents the node and the child node of Leadership and decision-making concept using NVivo software.

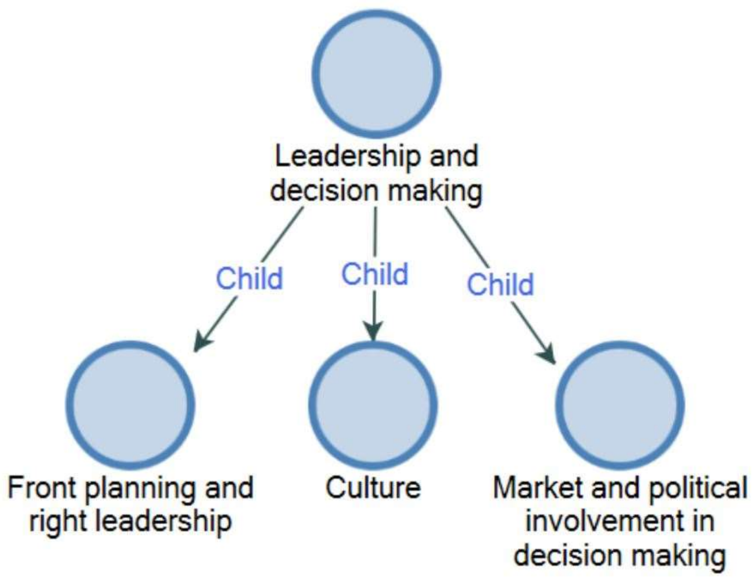


Figure E.20: Node map of Leadership and decision making.

➢ *21 Disaster and projects types*

- **Disaster type**

Participant P4 stated that risk management in recovery projects ***depend on the type of the disaster***. For example, it is completely different between the natural like earthquakes and human made disaster airstrikes.

Participant P11 believed that disaster represents risks that are not in BAU. You got much more national cooperation in a post-disaster environment which is operated in human environment that substantially different from BAU, the expectations from public or stakeholders are different, the way that projects operate taking into account the external involvement such as public, and even the physical environment itself. It is ***depending on the type of the disaster***. For example, in the context of earthquake there is a possibility of further aftershocks. Involvement of people dealing with their own damage, and the operation is creating more interruption around them. All these types of differences between projects in BAU and recovery projects, ***it is more about the combination the impact of the disaster in the environment and what that means for us to operate with that environment***.

Participant P24 mentioned that underground work represents the greater risks in earthquake disaster recovery because it is unforeseen while out of the ground there are not many surprises, ***the unknown is what is in the ground***, even after geo reporting, you still getting surprises. ***Most of our risks set below the ground after earthquake***.

- **Project type**

Participant P1 mentioned that the project type influences the risk management in recovery projects. ***Big projects*** are much ***more complex***. For example, these projects may face limited investigations also; it has lots of pre-work to be done. Some of it has shortage in quality assurance because of no complete design due to there is no time and it is emergency.

Participant P4 stated after disaster situation, it is more about Prioritisation. You have to secure the level of services projects such as drinking water, and sewage then you go with structure projects. ***Underground is riskier than above the ground***.

Participant P6 mentioned that all the risk management concepts in recovery projects are valid for ***different type of projects***. Each project has its own risks. You still look at risk mitigation, but the degree of risks could be different. But it is under the same umbrella headings. It may be more or less impact.

Participant P9 stated some projects are higher risk than others for example, ***underground work*** or projects related to external suppliers or to external factors.

Participant P10 explained that ***the complexity of the project*** is affecting the risk management and the type of repair, if you are building new or repairing. For example, one company with one bridge project, the number of risks found there with no enough ***investigations*** was huge. There is a timeline and need ***emergency response*** to be done. There are ***recovery processes*** you need to readjust and look at risks even there is no time.

Participant P15 stated that the more complex the projects are; the more the risks.

Participant P17 said that project ***complexity*** is important and affecting the risk performance.

Participant P19 thought risk management in recovery projects depend on the type of the project, for example, that ***large structure projects have bigger risks***; pressure mains have more risks in a large scales and wider exposer.

Figure E.21 represents the node and the child node of disaster and projects types concept using NVivo software.

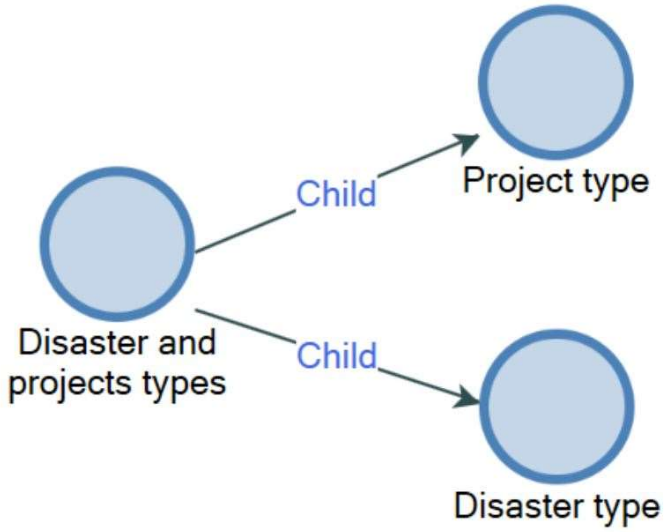


Figure E.21: Node map of disaster and projects types.

➢ *22 Loss impact analysis and investigations*

Participant P2 stated that in recovery projects, there is ***no time to do proper investigation***. In some cases, you have to just go and design what you physically see and carry on. If you did further investigations, it may mitigate the risk, but once again how you deliver a programme as big as this with ***short amount of time*** if you do a lot more investigation. ***Investigations mean more time and money***.

Participant P9 mentioned that for recovery projects, ***upfront planning*** and ***more investigations*** are critical.

Participant P10 discussed the important of having initial investigations. There are different levels of investigations; and as the risk changes, the investigations changes, and the processes changes. When we are talking about funding, the funders want to know exactly what they cover, that is when you get more refine in investigations. For example, ***CCTVs for the initial investigations and after repairs*** for main pipelines and for laterals; it is a huge job to do, 1600 km to check in Christchurch. Initially, we just throw a camera after the eastern side of Christchurch; it was all about what the risk of network collapsing, and that to give us fundamental ideas of the size of the sewage network problem after disaster. We found the soil will not able to stand housing here; we found also whole areas that need to be relined with whole new system.

Participant P1 explained after disaster, we need to ***assess where we are now and where we are going***. From project point of view, you have to evaluate the project and the damage and evaluate what is the best for us and our staff.

Figure E.22 represents the node and the child node of loss impact analysis and investigations concept using NVivo software.

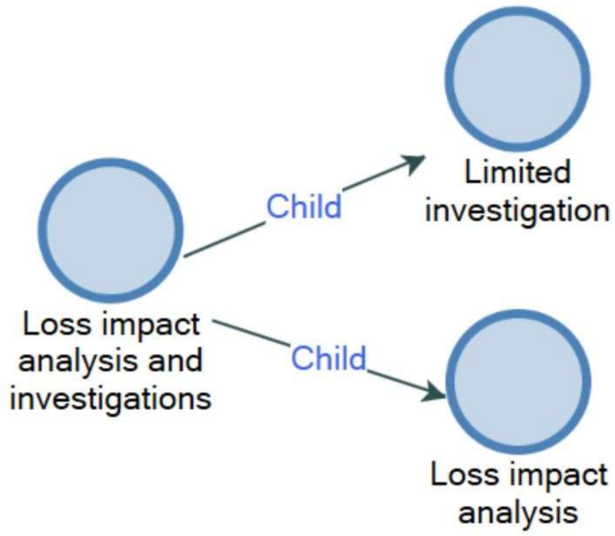


Figure E.22: Node map of loss impact analysis and investigations.

➤ *23 Productivity*

Participant P2 stated that ***a lot of risks in risk register could slow things down*** if we not solve it ***quickly*** which shows that risks are connected to productivity.

Participant P3 stated that post-disaster productivity is higher because they are trying to get the job done as fast as possible (ASAP).

Participant P9 mentioned that the productivity linked to the risk management because ***productivity will be reduced if some risk happens.***

Participant P10 explained that there is always risk associated with increasing productivity, the ***time, cost, quality triangle***, if you are trying to squeeze time, cost and quality could blow out. Time is becoming more critical in post-disaster, because ***people need to back to normal ASAP*** and also ***humanity***, which could affect ***quality*** and ***cost***.

Participant P9 explained that implementing risk management ***eliminates surprises*** basically which will impact the profit, so it is very important we improve the productivity by doing effective risk management.

Participant P14 mentioned that risky projects will take longer, and it will affect productivity.

Participant P15 stated that the higher productivity is the higher the risks.

Participant P19 mentioned that there is a huge volatility in the productivity because people try to figure how to work after the earthquake. After the conditions are slowly settling down; the productivity could increase.

Participant P24 mentioned that the main problem with ***productivity*** is around planning, ***insufficient planning*** increases the risks and the losses.

Figure E.23 represents the node and the child node of productivity concept using NVivo software.

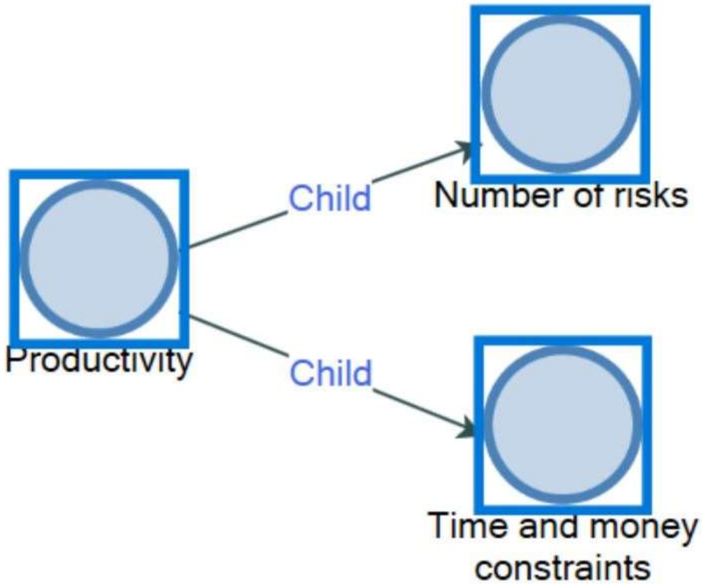


Figure E.23: Node map of productivity.

➢ *24 Temporary works and traffic management*

Participant P2 explained for earthquake related, like Christchurch, there is a lot of earthquake still happening, ***aftershocks***, it is a safety problem, and you need to make sure that the ***temporary work*** you design is going to stand in place. You have to check what new risks arise to the design.

Participant P2 explained that there is a risk that temporary works is not sufficient, and it could collapse due to aftershocks.

Participant P3 illustrated that recovery projects includes lots of ***temporary works*** to support the buildings and the work. For example, with retaining walls we always have temporary work design. We always monitor excavation phases, temporary anchors, temporary shoring. You can't let people work with the risk of something may fall over."

Participant P1 mentioned that ***managing the traffic*** is huge challenge in recovery projects because it is impact how the people are going to go back to their families to make sure they are safe during the recovery.

Figure E.24 represents the node and the child node of temporary works and traffic management concept using NVivo software.

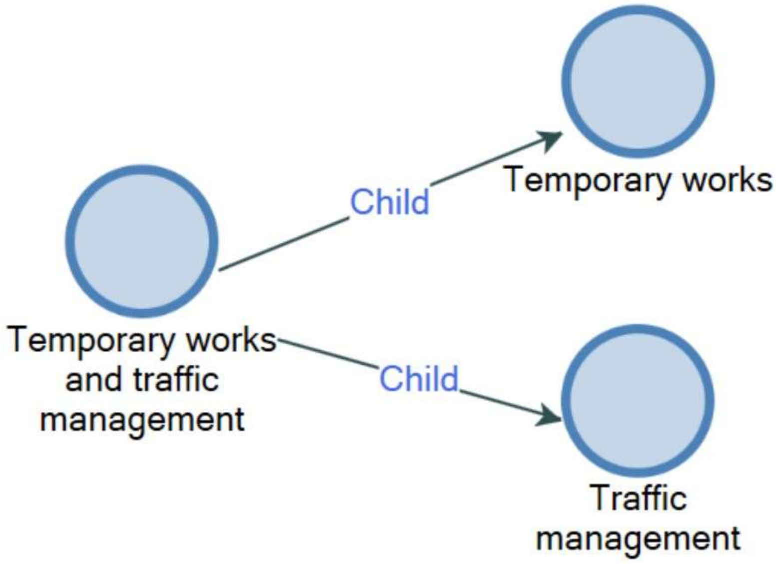


Figure E.24: Node map of Temporary works and traffic management.

- ***25a No of Request for Information (RFIs)***

Participant P2 stated that the number of RFI could play a massive impact on risk because they are generally ***design base***. Staff asks clarifications about design or anything unclear related to the project.

Participant P4 augured that the number of RFIs are linked to risks, the more RFI, the more risks; it ***is good indicators for risks***. If you have ***clear instructions and clear scope***, it reduces the risks. One of the main risks is ***the insecurity of design***. Direct after disaster, you are dealing with ***unknown geography and unknown services*** and design that build but cannot be applied after disaster. ***You don't have enough proper investigation or planning after disaster.*** You do the stuff as it goes.

Participant P6 stated that RFIs are created when delivery engineer has a question. He may not interoperate the plan correctly. His risk mitigation process is to create RFI or to give feedback. If we need to change something, it may become a ***WSC***. If WSC is a significant WSC, then it may have impact on the ***timeline and the cost***.

Participant P9 explained that ***the less RFI, the better the risk performance***; RFI represent potential inquiry which could be transferred into risk if it not managed.

Participant P10 thought that the main risk in recovery projects that you ***don't have luxury of time***. For example, the project that needs 2 years for design; you want it in 8 weeks. The ***RFI*** is there to define that the design is not fully finalised; it is the best that you will get for that timeframe that have been assigned. The risk is you are trying to get things done in a short time, so the people of Christchurch can back to life faster instead of waiting 5 to 20 years more. The risk come when you are trying to speed things up then you get RFI and the RFI change to be ***WSCs***.

Participant P11 mentioned that the RFIs represent thinking well of what need to be done, ***spotting the gaps***, dealing with these gaps ***identify solutions***, it is a part of ***good project management*** and ***risk management***.

Participant P14 stated that the more RFIs, the more risks; it represents the unknown factor.

Participant P15 mentioned that the higher the RFIs numbers are, the higher the risks.

Participant P24 explained it depends on the project, if many RFIs because it is a ***challenging project, need a lot of support from the design team***, you could argue there is a correlation between large ***risk register*** and ***RFI*** number.

- *25b Work scope changes (WSCs)*

Participant P3 explained that everyone under pressure in recovery projects to deliver the projects as soon as possible, and the designers are not an exceptional from that. That is why it is probably not the best design, not the safest design or the way to do it. So, it is probably will be lots of WSCs and lots of RFIs. In a BAU, you may plan for a project for a couple of years where in post-disaster, you only have couples of months, so we definitely will have lots of risks you don't have it in BAU. ***No enough geotechnical information***, but you need to build something because of greater risks need to be avoided. Early Contractor Involvement (ECI) is important and it works, but it is limited due to time limitation. Sometimes you get ECI from another team, and they missed something then contractor need to review, and it happen often in the alliance. ***It only works if the designer listens to your comments as well***.

Participant P4 explained the maturity of design through the recovery programme lifecycle. For example, projects that were designed in 2011, which was immediately after the earthquake, ***designers***

are new to the area and the situations that is why bad design is a high risk. After 2013, you can ***see the increase of the quality of the design***.

Participant P5 believed that numbers of WSCs are affecting risk management, as with more work, you are facing more risks.

Participant P11 thought the number of WSCs could affect the risk performance, they are to add scope***, if you increased the scope; the new scope would come with its own risks***.

Participant P14 mentioned that in SCIRT we were trying to reduce the number of WSCs. Some projects they have more risks than others, ***projects with more WSCs on it, it is indicator that something might be wrong***, ***it depends on the project***.

Participant P15 stated if WSCs increased, it will increase the project risks.

Participant P17 stated that in recovery project, ***we don't have clear scope definition***; ***we don't have full survey which will increase the number of WSCs***. In BAU, work is clearer and defined. It is affecting ***risk performance***.

Participant P19 explained that ***the projects with large number of WSCs are worst performance than low. The more defined scope of work, the lower deviation from the TOC and the higher the performance***.

Participant P20 mentioned that the huge number of WSCs has the potential to ***distract*** us from doing a proper risk management. There was argument inside SCIRT to just ***disregard the WSCs, because so much time and effort being spend for unseen events***. There was argument to change the budget. So, we thought about to change the budget to allow for ***unseen risks***. But people got distracted of what they have been given to build the job. In recovery projects, ***energy was focused in the wrong area*** so the pain or the gain model was affected. ***Energy should be focused in how we can deliver in achieving work under TOC not how to change the budget and get WSCs***.

Participant P24 stated that ***if the WSC in the risk register, then it is not a WSC because you allowed for it in your contract***. ***WSCs deals with scope change have not been identified as a risk in first place***.

Participant P25 stated that ***a job with more WSCs, it will have more risks***."

Figure E.25 represents the node and the child node of WSCs and RFIs concept using NVivo software.

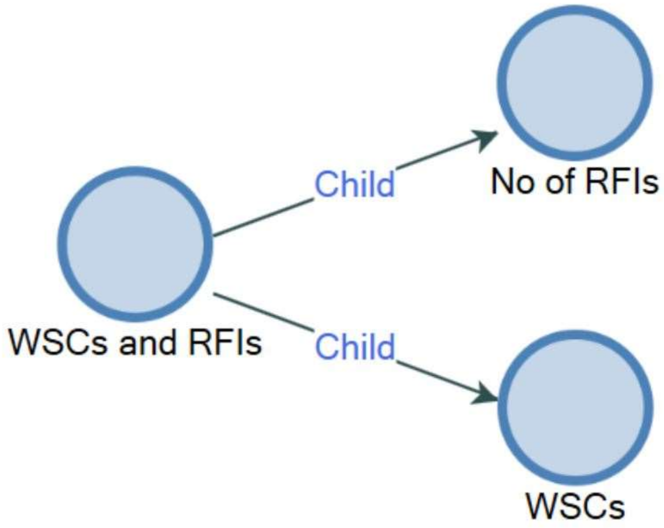


Figure E.25: Node map of WSCs and RFIs.

➢ *26 Lessons learnt*

Participant P1 believed that it is important to learn from the previous disasters and doing front planning is important as ***we need to understand when we have another disaster where we should go and what we are going to do***. So, when we started rebuilding team we don't take long time.

Participant P9 explained that identifying the risks early on is essential; ***we definitely need improvement in risk assessment***, ***it is important to have experience from previous projects***. You can reduce the impact of the risk of you identify it early enough. ***There is a need to change*** ***the sensitivity of the employees towards risk***.

Participant P11 mentioned that it is always a question of ***scale and natural of work in recovery projects***. Dealing with risk is a learning curve. We are doing something new, ***something different***. We have to change the way we operate if there is risk associated with that. And it is all about ***lessons learnt*** where there are people done it before. It is about ***making use of external expertise*** to ***add value*** to your risk assessment management exercise. It is to get the benefits of the experience developed and getting the lessons learnt. ***The key is to get the right people to review***.

- **Collaboration**

Participant P13 stated we should look ***collectively***; make more new ***workshops*** of risks; ***internally and externally***. We have a lot to do with ***collaboration***. There is a lot to learn in recovery projects.

- **Smarter information system and document control**

Participant P21 mentioned there is always learning curve with unique projects and it is going to be a huge task and a very good exercise. For example, inside SCIRT, delivery teams started to do the project under TOC. ***All parties need to be involved for better outcomes. Even SCIRT was good alliance,*** there is always a place for improvement and lessons learnt using the database and the ***information systems***.

- **Risk management best practices**

Participant P2 explained that inside SCIRT, every company has their own risk management culture. Some companies holding the risks till the end of the project, some ***releasing the risks as far as the project is going along*** which was highlighted as the best practices.

Participant P24 illustrated that risk management in recovery projects depends on the degree of maturity inside each company; some delivery teams have ***mature programme management practices*** and ***tools***, ***practices***, ***systems for project management***. However, it is important that the delivery teams have aligned risk management approach with ***bigger picture of how risks will be managed***. Some teams have been in ***step learning curve*** therefore, ***procedure need to be in place to manage risks***.

- **Shared risk management**

Participant P11 illustrated that working in alliance was a benefit to the recovery programme, because there is a great opportunity to ***share risk management***, not just with your direct stakeholders, it is with other peoples as well and example of that is central city repairs, blocking the streets and cause unacceptable ***interruptions*** to the business, people were operating in the central city and the demolitions and the external contractors from out of the programme were working in the same areas. All these type of interaction risks should be managed. It is a part of what could be called ***integrated recovery effort*** with this ***coordination mechanism*** to achieve the desired deliverables.

Participant P1 mentioned that external and internal audit is a good way for learning best practices. We can carry on and look for improvement and applying the learning by learning from our early projects, it is the best way to find the best respond and apply it elsewhere which could save money. ***External or internal audit it is there for share the knowledge***. However, companies can manage their own projects risks.

Participant P13 explained that knowing the actual risks around the project by sharing knowledge however, ***we need to understand each other's*** by ***open talking***, g***et around the table***. We can learn from the other delivery teams with more ***open dialogs***.

Participant P14 illustrated that ***communication and sharing knowledge is very important***, if you got different issues in different crews and teams, if people talking to each other's, and see what could go wrong; then you can have plans to stop it from happening in future projects in the same programme for the other teams. For example, in some project where it was needed to line a big pipe which cause us big issues, and we know that other company is looking to do the same thing with their project; we changed the methodology from lining to dig and trenching to mitigate the risk. So, we have two different teams working is similar projects with similar risks and similar ground conditions and ***they change the methodology to mitigate the risks by doing effective communication***. It is so important; things could go wrong if people not communicating across also, we could save money and time because of effective communication.

- **Innovations and technology changes**

Participant P2 stated that technology changes might ***assess*** in mitigate and ***reduce risks*** easier cheaper faster but that would not be a big difference from a post-disaster except I see SCIRT done more researches and investigations regarding materials and ***new methodology*** that I never seen before.

Participant P3 explained that you need plans for ***aftershocks*** then your methodology should reflect that. Where in BAU, you might have one methodology that can be used all over the place where in post-disaster, you may have floods in one area and you need to ***change your methodologies.***

Participant P9 stated any new technology might help to mitigate the risk.

Participant P14 illustrated that ***the way we are doing things have changes with time***. The used material has changed. You are getting more resilient type of product. Like using pipes that just going to move not crack under earthquakes.

Participant P17 believed that there are ***new techniques and methodologies*** that we need to address to avoid delays in post-disaster.

Participant P19 said that it is related back to ***quality assurance*** over the five years of SCIRT. To save the time with over than 700 projects, ***you need innovations***. It is important elements.

- **Feedback loop**

Participant P7 illustrated the importance of feedback loop in lessons learnt and decision making in recovery projects. For example, there was a different in the loop of the ***decision-making*** inside SCIRT and the response to it could be better with better ***feedback loop***. As a delivery teams we could change the decision-making processes in SCIRT from certain perspectives by using feedback loop which is based on feeding up the delivery knowledge to the design team and change their design to more practical solutions.

For example, for a lateral pipe job, the delivery team and/or the subcontractor should assess the risks and the conditions and advice if that design going to work or not in the real field. That have been improved at the end of the programme where SCIRT started assign the main contractor and the subcontractors to go and do their own assignment, do you recommend relay? Do you recommend no action? It is more into a cooperation based on trust to give the choice for delivery teams to choose the right option, some projects we lined; we wouldn't line it at all.

Figure E.26 represents the node and the child node of lessons learnt concept using NVivo software.

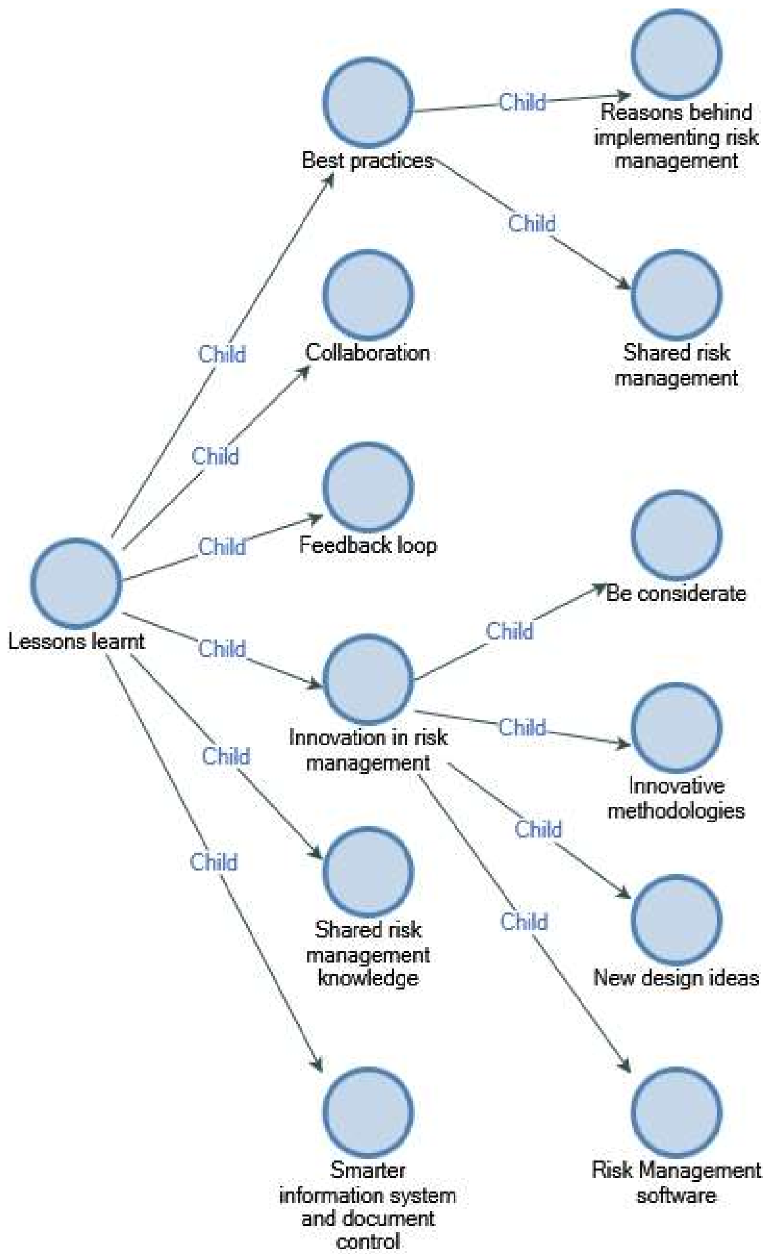


Figure E.26: Node map of lessons learnt.

➢ *27 Smart post-disaster risk management approach*

- **Lessons learnt**

Participant P2 explained that risk management in recovery projects should consider a balanced ***perspective of the speed and what need to be delivered versus what could wait***. For example, the investigations, if the project was carried out in the start of the programme, the investigations would be very little because of emergency works. Also, it is ***depending on the stage the project in***. For example, if you are in design team, the design risks are your priority number one, when you are in delivery the construction risks are your priority, thinking completely differently risk management wise.

About ***risk management performance***, it is hard to be measured but if so, there is no different between post-disaster and before from the construction perspective. It should be measured as if all the unforeseen risks have been identified in the risk register. ***Every risk should be identified and managed.***

Participant P23 said it comes back to getting the ***speed of learning into the solutions*** that we deliver. ***Getting learning before the disaster happen,*** so, the local authority and government could cooperate that to scenarios to repair or deliver projects. It is a key to ***get a head of the game*** when a disaster happens, it is too late, and time is essential. Therefore, it is important to have manuals and plans ready to be implemented when the disaster happened.

- **Early assessment from early projects**

Participant P21 explained that in recovery projects especially in such big programme that contained similar projects, ***they keep facing similar risks***. This is a huge benefit if the knowledge and the experience used from the old projects in the same programme, ***lessons learned and feedback loop.***

Participant P14 mentioned that SCIRT is an umbrella organisation to fasten the procedures and facilitate the recovery. ***Time is critical in post-disaster***, for example, we need to not waste time in asking for ***consenting***; so SCIRT reduced this risk. ***SCIRT was there to speed up the procedure***. The benefit of working under one umbrella is lessons learnt from previous projects. For example, risks happen in one project could be similar to another and this is where we can get ***lessons learned*** to the other projects in similar situation or area. Find out similar issues and avoid the risk before it happens in the new project. Use an ***early assessment from early project to help accelerate new projects***. It is a ***cooperation attitude*** to share the knowledge between teams to avoid falling in the same mistakes.

- **Smarter procurement strategy of one umbrella and single identity**

Participant P21 explained how ***the procurement strategy*** can reduce the risks and endorse more effective risk management. After the first earthquake and before SCIRT establishment, city of Christchurch was divided into a number of pots and the asset owner allocated the work to two parties and pots were considered to be the three waters mains, roads and bridges. It was more like immediate response model, that recruitment model works fine for the earthquake and lot of work done. Delivery teams engage the designers and check with the city what they want to achieve. The designers come with options and the asset owners choose the proper option. The detailed design was done in fast track. That work fine until the second big earthquake. Everybody see that it was huge challenge for the city council, government and the asset owners to deal with such big magnetite. So, NZTA ***thought about new model*** and they looked at all the options and that is where SCIRT alliance has been created. The alliance was set up and there were risks around***. NZTA promoted the alliance because they used it in previous big projects and it works where a*** lot of urgent work was done in fast track and cost efficient and people been attracted. It took time to prepare choose the procurement, however, if there was a clear ready ***procurement plan*** in place when disaster happen, you will not waste time to think about it.

Participant P6 explained a lot of the risk was considered when SCIRT was established. Some of these risks have been driven by the five recovery organisations and the alliance. All parties went through their appropriate risks and considered how ***to progress forward as a single identity***.

For example, they managed cost using TOC to manage some financial risk factors, so the cost not below out. Also using KPIs to manage schedule using Schedule Performance Factor (SPF) to keep projects on time and mitigate the risks. Simple things like that, risk mitigating the schedule below out. Quality risks, ***speed affect the quality*** that is why there was lots of pressure to get the quality right that was another risk to mitigation even it is recovery projects, the asset owner still want the project with right quality on time and budget.

Participant P11 explains one of the main aspects in risk management in recovery project is to ***motivate the people*** to get involved in recovery in the first place, that comes ***from the bottom up*** but at the sometime for any organisation, ***from the top down***, to establish and encourage the ***culture*** that work best for this organisation. For example, SCIRT was not a normal alliance, it was all about ***collaboration***, even the culture was impacted by the ***competitive tension*** that been developed but it was a good combination of both. It is hard to force culture on the recovery teams as they may give bad service, so whatever you are putting down have to be something they can identify and follow with their heart as with their minds. ***That is why it is important to identify their drivers in the first place and look how this fit what they want to the organisation culture to be like and*** SCIRT was an example of where that was successful. Nevertheless, it is about the ***systematic way*** of all the risk been identified and controls developed in place to cover all the risks. ***The other thing is front planning of the risks***.

Participant P18 thought in project level; the ***different cultures are clearer.*** For example, in dealing with the ***KPIs***, the large component of that affecting the risk management and the way they are managing risks inside the projects, each company had its own way of managing risks. However, ***with overhead structure like SCIRT, that organisation structure merged to be one which called alliance culture*** and it is ***optimise to most effectively manage the risk.*** This is the value of the alliance to ***put the different culture aside and effectively manage the risks***.

- **Early risk awareness and competition model**

Participant P20 stated that the word ***intentionality*** is a big factor of reducing the uncertainty. Some of the intention may not succeed but that doesn't reduce the important of your intention to do it and creating a recovery system like SCIRT, is the way of how to do it and deal with it.

On the other hand, creating a competition in the model was essential. For example, if we allocated separate areas to each delivery team; it will limit the competition. The key element of SCIRT is the success of doing work. ***The attitude and the governance performance are driven by competition.*** They make a fee over TOC to the projects they manage. It is very important. If companies will do all the projects in one area; this will reduce the competition between the teams and that may affect the performance and the delivery of the programme. Even in City Centre, it was successful. One of the ***lessons learnt*** is to ***create competition, working as a team, sharing good stories, learning from our mistakes***.

SCIRT model is smart way of cooperation which called the pain/gain model. If companies beat the TOC, they will split the benefit with the client. If they deliver over TOC, they will also split the penalty. So, if you are doing well, everybody wants to know how you are doing well, smarter setup to learn from others. It is driving the overall performance and productivity. ***The lead to share the knowledge is very powerful.*** In the case of oversight, the risks, the ***competition model*** was more to ***risk awareness***.

- **Leadership with critical thinking skills, honest and fair trade**

Participant P13 stated that risk management always in construction but in the last number of years, it become more important, however, ***critical thinking*** is required in recovery projects, it is not about the cheapest price anymore. Nowadays, it is about how to do proper risk management attributes, there are number of factors affecting that like being ***honest and fair***. Also, try to identify all the risks. Since the earthquake disaster, there were many ***aftershocks***. Money is the big driver in construction industry, because of the disaster, the market lost significant amount of workforce which caused some setbacks in the beginning, but after a while, the situation got better with the existence of ***good leaders. The complexity has been broken down by the brain power***.

Participant P26 stated that ***the risks are different in recovery projects and they relate to other threats and that is add to the complexity of risks***. Therefore, it needs critical thinking from people to identify and manage these risks.

- **Proactive with effective prioritisation strategy**

Participant P9 stated that ***Proactive*** and ***experience***, the ***culture*** to be open to discussion to accept the changes after disaster are critical aspects to effective risk management in recovery projects.

Participant P11 though that management of risk in related to ***culture*** doesn't change too much between big organisations regarding ***the systems and the processes***. ***In BAU, your priority is to make a return, time cost quality pretty straight forward. What becomes important for a disaster is the set of objectives and the things that you try to achieve***. So, in that kind sense, the culture has to change from mind business like culture to once taking into account ***the human dimension*** and everything else is happening around in terms ***of the community and other stakeholders***. In BAU situation, it is less considered. In recovery projects it is influenced by ***the drivers of the involved people*** as they want to help the city to recover. It is a bit of ***culture shift*** from day one. In the beginning, we may lose a bit of a proper risk management in your way of fixing everything due to emergency and time constraints. It needs to be a ***productive culture*** but in a post-disaster environment, the ***emotions*** play more than BAU which definitely impact on the culture.

Participant P17 mentioned that it is important to consider keep ***continues improvement*** and seek the best practices to keep ***industry developed and up-to-date***.

Participant P20 thought the interesting thing is that ***none of the strategic risks happened*** as SCIRT had very good mitigations methods ***on front and been proactive with programme risks.*** There are areas in programme management SCIRT could do better. In many of the risks, there were early warning measures ***of what is happening over time and seeing the trends with cost overrun and time***

over run ***using intelligent information systems***. SCIRT got five delivery teams competing; SCIRT knew in the outset some would be better than others that is why SCIRT left delivery team to perform. However, ***SCIRT didn't recognise that the level of experience inside these teams were as low as such in some cases.*** ***SCIRT should do more effort to support them and increase the experience level.*** Many of the problems occurred because of ***new inexperience staff*** was involved in the recovery due to ***the lack of resources***. The other thing about SCIRT, it is quite different from normal business. Delivery teams got paid for every cost occurred which reduce the pressure in the delivery team to concentrate in deliver the work. Also, ***document control*** was given right in the beginning of the programme.

Participant P21 it is important to ***understand the risk,*** so it could be managed properly. From experience, the more successful project one appears to have a ***comprehensive risk register*** in place regularly updated and trying their best to mitigate the risks and that also with opportunities. Companies could make some gain from risks. Monitoring and tracking risks also is essential. For example, tracking cost to complete and monitor the project through its life and take the steps to avoid the project overrun. ***We noticed when look to project why they over run, we found the good use of risk register is missing.*** Similarly, some projects you think in the beginning they are going to struggle to do them on budget, but when you investigate you find the project manager have ***a comprehensive risk register*** and they done proper risk management steps along the way to mitigate and minimise the risks and he be able to bring them under TOC with ***good risk management to a successful delivery, it is more practical approach not just theoretical.*** 700 projects make up the total SCIRT to be done in short time but there are common seen coming over, most of trenching works some near the river, some near high dense residential areas. Each project has its own set of risks but there is common seems between these projects and common approach of how to identify and manage risks which is the benefit of having alliance model.

- **Flexibility, culture and positive attitude**

Participant P12 explained that ***the flexibility*** of how to manage risks onsite is critical in meeting the project objectives. For example, if there is aftershock earthquake over 5 magnetite, all the work needs to stop, and everything need to be reassessed which may cause delays but because safety is the first priority in recovery projects, work should be stopped, anything below that will be probably site specific. ***SCIRT came up with this procedure to deal with these types of risks.*** Also, the ***personal risks***, is more about ***support*** and what people are going through like staff and family circumstances which also required ***flexibility***."

Participant P20 indicated there is direct relationship between ***culture*** and risk management. Even the recovery alliance looked as one unit, but SCIRT in the beginning of the recovery programme agreed to ***not force any management style to the delivery team***. ***Each company has its own style and culture.*** SCIRT did not been created to change them. However, ***culture is affect attitude to risk*** but because delivery teams worked in alliance where best performance gets rewarded, all the parties ***aligned their culture*** with SCIRT then the attitude became than normal.

- **Intelligent risk management systems and procedures**

Participant P19 stated that ***recovery organisation needs to know the quantum of the faced risks and that needs intelligent integrated systems***. If a business system relay on a single team member within the organisation, and there is a disaster, there is NO way that it can be rescaled up with a paper work base system. If you have a system which is not relay in a single person, everybody in your organisation knows about the system. Then when disaster happens, the impact will be less. Once you are available and running, you should be scalable. ***If you got a risk management system which is scalable, that what you need in such situation. Well established system that can step up and gear up to accelerate 12 times faster than BAU.*** ***Scale problem could be solved by additional resources or by technology***. For example, in SCIRT, we set up the project centre web base ***information system***; it was a bit hard in the beginning. After 5 years, you got the benefits, everything in one system. In emergency situation, you will need some technology that step up and be scalable 10 times, 100 times rate, ***so you have to have technical solutions that allow you to scale up very quickly with business systems***.

Appendix F: Published Papers

Paper published in the 2018 Construction Research Congress

Risk Management and the effects on project success

Eric SCHEEPBOUWER[1], Ashi EZZ[1], Brian GUO[1], Daniel VAN DER WALT[1]

[1]University of Canterbury, Department of Civil and Natural Resources Engineering, Private Bag 4800, Christchurch 8140, New Zealand, Tel: +64-3-3642235; Fax: +64-3-3642758; Email: eric.scheepbouwer@canterbury.ac.nz

Keywords: *Early Contractor involvement, risk management, cost certainty*

ABSTRACT

The general consensus in the construction industry and academia alike is that good risk management is pivotal to project success. However, quantitative evidence supporting this conjecture is lacking. SCIRT is an alliance formed in response to the 2011 Christchurch earthquake and had been tasked with the repair of the city's horizontal infrastructure. The SCIRT rebuild provides the opportunity to compare projects with different risk management strategies and analyse the effects of changes in scope and forecasted final cost on the project success. Statistical analysis confirmed that early contractor involvement and risk workshopping significantly improved the financial performance of projects. In addition, changes in project scope were linked to poor financial performance. Finally, the level of risk management was shown to influence the relationship between the frequency of changes in the forecasted final cost and the financial performance of projects. It was concluded that enhanced risk management techniques employed in the design stages of a project provided project managers with a better platform from which to manage project risks. When this platform was provided through early contractor involvement and risk workshopping, an increase in the frequency of forecasted final cost changes led to improved cost certainty. The results of this study quantitatively support the intuitive notion that proactive risk management has favorable effects on the financial performance of projects. This study contributes towards increase the understanding of how a better overall performance of a construction project is associated with the improvement of the risk maturity inside the organization approved by statistical and qualitative data analysis of over 200 projects. This should encourage construction practitioners to support the proactive risk management and risk maturity as a precursor to more effective project delivery.

1. INTRODUCTION

The US Federal Highway Administration initiated its Every Day Counts program in 2010 which was aimed at encouraging state and municipal transport agencies to "better, faster, and smarter ways of doing business." (Mendez 2010). Arguably the taxpayer should rate something higher than "cheap" buildings, utilities, roads and bridges (Lopez et al. 2016). Similarly in New Zealand, after Christchurch's infrastructure was devastated by the earthquakes in 2011, the public agencies needed a better, faster and smarter way of doing business. The government turned to alliance contracting as a means to bring all the actors together and cut through routine challenges to progress by maximizing collaboration between clients, design consultants, and construction contractors in order to accelerate the delivery of over $2.4 billion worth of infrastructure. Once the emergency requirements after the disaster were satisfied, demonstrating value

Appendix G: Crisp set matrix of QCA for the 100 projects from SCIRT

Cases/ projects	SPI	WSCs	IR	NCRs	CPI	Outcomes RMM
1	0	0	0	0	0	0
2	0	0	0	0	1	1
3	0	0	0	0	1	0
4	0	0	0	0	0	0
5	0	0	1	1	0	0
6	0	0	0	0	0	0
7	0	0	0	1	0	0
8	0	0	0	0	1	0
9	0	0	1	0	0	0
10	0	0	0	0	0	0
11	0	0	0	0	0	0
12	0	0	1	0	1	1
13	0	0	0	0	0	0
14	0	0	0	0	0	0
15	0	0	0	0	0	0
16	0	0	0	0	0	0
17	0	0	0	0	0	0
18	1	0	1	0	1	1
19	0	0	0	0	0	0
20	0	0	0	0	0	0
21	0	0	0	0	1	0
22	0	0	0	0	0	1
23	1	0	1	1	1	1
24	0	0	0	0	1	0
25	0	0	1	0	0	0
26	0	1	0	0	1	0
27	0	1	0	0	1	0
28	0	0	0	0	0	0
29	0	1	1	1	0	1
30	1	1	1	1	1	1
31	1	0	1	1	0	0
32	0	0	0	0	1	1
33	0	0	0	0	1	0
34	0	0	1	1	1	0
35	1	0	1	0	0	0
36	0	0	0	0	1	0
37	1	1	1	1	1	1
38	0	0	0	0	1	0
39	0	0	0	0	0	0
40	0	0	0	0	1	0
41	0	0	0	0	1	0

Cases/ projects	SPI	WSCs	IR	NCRs	CPI	Outcomes RMM
42	0	0	0	0	0	0
43	0	0	0	0	1	0
44	1	1	0	0	1	0
45	0	0	0	0	1	0
46	0	0	0	0	0	0
47	0	0	0	0	1	0
48	0	0	0	0	1	0
49	1	0	0	1	0	0
50	0	0	0	0	1	1
51	1	0	0	0	1	0
52	0	0	0	0	0	1
53	0	0	0	0	1	1
54	0	0	0	0	0	0
55	0	0	0	0	0	1
56	0	0	0	1	1	0
57	1	0	1	1	1	1
58	0	0	0	0	0	0
59	0	0	0	0	1	1
60	0	0	0	0	0	1
61	0	0	1	0	0	0
62	0	0	0	0	0	0
63	0	0	1	0	1	0
64	1	0	1	0	1	0
65	0	0	1	0	0	0
66	0	1	1	1	0	1
67	1	0	0	1	0	1
68	1	0	1	0	0	0
69	1	0	0	0	1	1
70	0	1	0	1	1	1
71	1	0	1	1	0	1
72	0	0	1	1	1	1
73	1	1	0	1	1	1
74	0	0	1	1	1	1
75	1	0	0	0	0	1
76	0	1	0	0	1	1
77	0	0	0	0	1	1
78	0	1	0	1	1	1
79	1	0	0	0	1	1
80	1	0	0	1	1	1
81	0	0	0	1	1	1
82	1	0	1	1	1	1
83	0	1	1	1	0	1
84	0	1	0	0	1	1

Cases/ projects	SPI	WSCs	IR	NCRs	CPI	Outcomes RMM
85	1	1	1	1	1	1
86	0	0	0	0	1	1
87	0	0	1	1	1	1
88	0	1	0	0	1	1
89	0	1	0	0	1	1
90	0	0	0	0	1	1
91	1	1	1	0	1	1
92	1	1	1	1	1	1
93	0	0	0	1	0	1
94	0	1	0	1	1	1
95	1	0	1	1	1	1
96	1	1	1	1	1	1
97	0	0	0	1	1	1
98	0	0	0	0	0	1
99	0	0	1	0	1	1
100	1	0	1	1	1	1

Vita

Ashi Ezz is Project Management and Project Controls expert with strong work ethics, qualified with Master's in project management and civil engineering degree. Over 18 years of professional experience in construction and infrastructure industry.

Ashi has a strong and extensive background in project planning, project controls, cost controlling, and quantity surveying. His experience is not limited to managing project controls team, develop and tracking the programme performance systems, and leveraging internal systems to facilitate improved efficiency and performance, planning, scheduling, risk management, coordinating, monitoring, reporting, and endorse programme management best practices. He has contributed to a number of worldwide projects include residential, commercial, and infrastructure facilities, the project size varies from less than one million dollars to over hundred million dollars with total cost surpassing 3 billion US dollars.

Permanent address: NZTA, 24 Anzac Parade Street, Hamilton East
Hamilton, New Zealand, 3216

This dissertation was typed by
<Ashi Ezz>
<2019>